RELATIONSHIPS OF PROBLEM SOLVING PERFORMANCE AND PSYCHOLOGICAL TYPE

By

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This investigation was an attempt to identify the relationships between Myers-Briggs psychological type preferences and problem solving behavior. The problem involved isolating a faulty component in a simulated logic network, a form of troubleshooting. Ninety electronic engineers and technicians at the Kennedy Space Center in Florida completed five logic exercises of increasing difficulty, using a microcomputer to display the exercises and record the subjects' responses. Subjects' time to solution, number of tests and replacements, number of errors, and number of redundant tests were recorded and analyzed.

Anticipated performances, based on Myers-Briggs theory, were largely supported in direction, with three expected relationships achieving the required level of statistical significance ($p < .05$). Significant interactions were observed for the EI type preferences and number of redundant tests. Statistically significant differences ($p < .05$) were also observed between sensing and intuitive types and two performance measures: mean number of tests and mean number of errors.

One intriguing outcome was the reversal of expected peformance for the JP type preferences with perceiving types outperforming judging types on every

measure of performance. Two of the differences in performance measures were statistically significant (p < .05), with perceiving types using fewer mean tests and fewer mean redundant tests than judging types.

Some intercorrelations between independent variables raised questions concerning the degree of influence of type preferences on problem solving performance. Post-hoc analysis to statistically eliminate the influence of other independent variables suggested that some type preferences were independently influencing performance measures to significant levels ($p < .05$): Intuitive types used fewer tests and made fewer errors than sensing types, introverted types used fewer redundant tests than extraverted types, and perceiving types used fewer tests and fewer redundant tests than judging types.

The anticipation was to link the research on learning styles and Myers-Briggs psychological types with troubleshooting behavior to establish a basis for applying type principles to the training of troubleshooters. Though only a modest relationship was observed, it was felt that the study provided a basis for additional work needed to understand and relate the complexities of troubleshooting behavior. Recommendations are given for further exploration of problem solving.

CHAPTER 1
INTRODUCTION

Troubleshooting electronic systems is a complex cognitive skill. Although troubleshooting has been studied since the advent of electronic systems, little is understood about the mental processes that occur during fault detection and diagnosis, making training and improvement of performance difficult. From his investigations of technicians troubleshooting electronic equipment, Gagne (1964) wrote,

> It seems likely that there may be a set of manipulations of instructions that serve to strengthen certain channels of thought and to weaken others, serving thereby to speed up the process of problem solving. But we do not know clearly what these manipulations are, or how to measure them. (p. 308)

The complexity of improving performance through training is compounded by a number of factors: the increasing sophistication of electronic systems, the lack of instruments to measure cognitive strategies occurring during troubleshooting, and the variation of strategies demonstrated by proficient problem solvers. However, if humans are going to be able to manage and maintain increasingly complex systems, it is necessary to understand strategies used in diagnosing faults and to reinforce successful and efficient problem solving techniques.

The cost to American military and industry for the maintenance of electronic equipment and the training of maintenance personnel is staggering. The United States Navy and Air Force spent $1.2 billion on electronic equipment maintenance in 1978 and expenditures have increased annually (Hunt & Rouse, 1981, p. 317). The growing diversity of electronic systems only complicates the problem. Chang, Manning, and

Metze (1970) stated, "as the range of problems to which digital computing systems have been applied has widened, the task of ensuring that a computer system is operating correctly has become steadily more important" (p. 1). W. Rouse (1978b) added,

> This problem is intensified by the fact that systems become so complicated as to preclude practice on each possible problem. Thus, humans will not be able to learn problem solutions by rote. Instead, they will have to employ more general problem-solving skills. (p. 258)

Automated test equipment aids human operators with complex systems, but as W. Rouse and S. H. Rouse (1979) explained,

> With increasing complexity [of electronics] this task presents difficulties because, while things may not fail too often, when something does fail, it can pose a very complex problem that can potentially be quite difficult to solve. While automatic test equipment may help the human to cope with complexity, the ultimate backup system is the human. Thus it seems reasonable to conclude that the study of human problem solving in fault diagnosis tasks is an important area of research. (p. 721)

Efforts in training troubleshooters have largely been focused on the half-split or binary chop technique, widely accepted as the most efficient means for identifying faults in complex systems. This involves dividing the faulty system into a feasible set, that which potentially contains the fault, and a non-feasible set, the set of components that cannot possibly contain the fault due to logical or structural considerations. In the half-split method, tests are performed to iteratively split the feasible set until the faulty component is isolated. The efficiency results from generally having to make fewer tests relative to sequential or random methods. However, as Goldbeck, Bernstein, Hillix, and Marx (1957) pointed out, "it's possible to teach subjects how to make half-split tests, but, in complex networks, people are not effective in identifying the feasible set" (p. 335).

Individual variations in troubleshooting behavior magnify the complexity of the training task. Gagne (1964) wrote, "the prominence of individual differences in studies of problem-solving attains the status of a crucial problem rather than simply being a

vexatious nuisance" (p. 309). W. Rouse and Hunt (1984); Allen and Hays (1984); Standlee, Popham, and Fattu (1956); Morris and W. Rouse (1985a); and Henneman and W. Rouse (1984) have all noted variations in problem solving strategies unrelated to troubleshooters' knowledge.

The variations in problem solving performance may be attributed to individual differences in perception and judgment, the bases of Carl Jung's theory of psychological type. As Lawrence (1984b) explained,

> In Jung's theory, all conscious mental activity can be classified into four mental processes--two perception processes (sensing and intuition) and two judgment processes (thinking and feeling). What comes into consciousness, moment by moment, comes either through the senses or through intuition. To remain in consciousness, perceptions must be used. They are used--sorted, weighed, analyzed, evaluated--by the judgment processes, thinking and feeling. (p. 6)

The Myers-Briggs Type Indicator (MBTI) was developed in the 1940s by Isabel Myers and her mother, Katherine Briggs, to make Jung's theory practical and applicable. The main objective of the MBTI is to identify an individual's preferences along four dichotomies: Extraversion-Introversion (EI), Sensing-Intuition (SN), Thinking-Feeling (TF), and Judgment-Perception (JP). Under Jung's theory and the extensions provided by Myers and Briggs, the preferences affect what an individual will attend to in a given situation and how that person will draw conclusions about what he perceives.

Need for the Study

While the MBTI has been used in investigations of learning styles and some aspects of problem solving, psychological type preferences have not been linked to strategies for troubleshooting complex logic networks. If a link can be established between problem solving strategies and psychological type, the growing knowledge concerning instruction of psychological types and troubleshooting behavior can be

associated, aiding the development of practical methods and procedures needed to train troubleshooters. Greater understanding will lead to an improved human ability to develop and manage complex systems, to develop job aids and intelligent systems for troubleshooters, and to apply currently existing knowledge for instructing people of the various psychological types, promoting efficiency in troubleshooting training and performance.

Purpose of the Study

The purpose of this study was to investigate the relationships between psychological type, as measured by the Myers-Briggs Type Indicator, and problem solving performance on computer-simulated fault diagnosis tasks. Troubleshooting performance was measured by the subjects' performance on a computer driven logic exercise that simulated a faulty electronic network and recorded subjects' responses during identification of a faulty logic component.

The exercise is similar to TASK (Troubleshooting by Application of Structural Knowledge) developed by William Rouse (1978b) and used previously to investigate human problem solving in generic fault diagnosis tasks (Henneman & Rouse, 1984; Hunt, Henneman, & Rouse, 1981; Johnson & Rouse, 1982; Rouse & Hunt, 1984; Rouse & Rouse, 1979). The exercise is a computer-driven simulation of a logic network (see Figure 1-1). The network, an array of logical "and" gates, contains a single faulty component which the operator attempts to identify by testing component outputs. Testing is done by selecting a component through keyboard commands; a component is good (working properly) if a test indicates a value of 1, while a value of 0 indicates a failed component. Results of a failed component are propagated through the network, so any

component "downstream" of a failed component will register as a fault when tested. The rationale and operation of the exercise are discussed in Chapter 3.

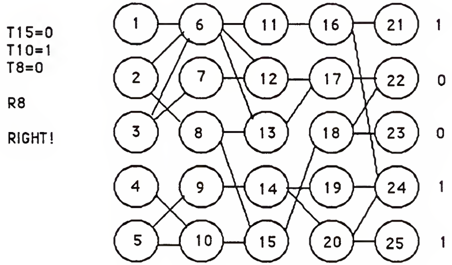


Figure 1-1
A Computer-Simulated Logic Network

The Research Question

When troubleshooting simulated logic networks, do people of the different type preferences, as measured by the Myers-Briggs Type Indicator, differ in performance with respect to time to solution, number of tests, number of errors, and non-redundancy of tests?

Statement of Hypotheses

Hypotheses A: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by psychological type preferences,

the following results are anticipated for mean time needed to identify the faulty component:

1. When individuals are grouped according to the extraversion-introversion preference, extraverted types will use less mean time to identify the faulty component than introverted types ($p < .05$).

2. When individuals are grouped according to the sensing-intuition preference, intuitive types will use less mean time to identify the faulty component than sensing types ($p < .05$).

3. When individuals are grouped according to the thinking-feeling preference, thinking types will use less mean time to identify the faulty component than feeling types ($p < .05$).

4. When individuals are grouped according to the judging-perceiving preference, judging types will use less mean time to identify the faulty component than perceiving types ($p < .05$).

Hypotheses B: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by psychological type preferences, the following results are anticipated for the mean number of tests needed to identify the faulty component:

1. When individuals are grouped according to the extraversion-introversion preference, introverted types will use fewer mean tests to identify the faulty component than extraverted types ($p < .05$).

2. When individuals are grouped according to the sensing-intuition preference, intuitive types will use fewer mean tests to identify the faulty component than sensing types ($p < .05$).

3. When individuals are grouped according to the thinking-feeling preference, thinking types will use fewer mean tests to identify the faulty component than feeling types ($p < .05$).

4. When individuals are grouped according to the judging-perceiving preference, judging types will use fewer mean tests to identify the faulty component than perceiving types ($p < .05$).

Hypotheses C: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by psychological type preferences, the following results are anticipated for the mean number of errors committed while identifying the fault:

1. When individuals are grouped according to the extraversion-introversion preference, introverted types will commit fewer mean errors while identifying the faulty component than extraverted types ($p < .05$).

2. When individuals are grouped according to the sensing-intuition preference, intuitive types will commit fewer mean errors while identifying the faulty component than sensing types ($p < .05$).

3. When individuals are grouped according to the thinking-feeling preference, thinking types will commit fewer mean errors while identifying the faulty component than feeling types ($p < .05$).

4. When individuals are grouped according to the judging-perceiving preference, judging types will commit fewer mean errors while identifying the faulty component than perceiving types ($p < .05$).

Hypotheses D: When performances of individuals troubleshooting a faulty component are grouped according to psychological type preferences, the following

results are anticipated for the mean number of redundant tests used to identify the faulty component:

1. When individuals are grouped according to the extraversion-introversion preference, introverted types will use fewer mean redundant tests to identify the faulty component than extraverted types ($p < .05$).

2. When individuals are grouped according to the sensing-intuition preference, intuitive types will use fewer mean redundant tests to identify the faulty component than sensing types ($p < .05$).

3. When individuals are grouped according to the thinking-feeling preference, thinking types will use fewer mean redundant tests to identify the faulty component than feeling types ($p < .05$).

4. When individuals are grouped according to the judging-perceiving preference, judging types will use fewer mean redundant tests to identify the faulty component than perceiving types ($p < .05$).

Hypothesis E: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by age, there will be no significant correlation ($p > .05$) between measures of performance and age.

Hypothesis F: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by years of experience in electronic troubleshooting, there will be no significant correlation ($p > .05$) between measures of performance and years of experience.

Hypothesis G: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by years of education, there will be no significant correlation ($p > .05$) between measures of performance and years of education.

Hypothesis H: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by sex, there will be no significant difference ($p > .05$) between measures of performance for men and women.

Subsidiary Questions

Do the different psychological types exhibit patterns of troubleshooting behavior that are consistent with other behavior patterns associated with their respective types, i.e., quick and impulsive tests for extraverted perceiving types versus slow and methodical tests for introverted judging types?

Do some psychological types take cognitive shortcuts and mentally "leap" to identification of a fault while performing only a small number of tests?

Do people of different psychological types differ in their abilities or tendencies to distinguish between the feasible and nonfeasible set of components?

Do some psychological types demonstrate greater anxiety or frustration than other types as problem complexity increases?

Do people of the different psychological types differ in their perceptions of problem difficulty?

As problem complexity increases, does the degree of flexibility in changing problem solving strategies differ among people of different type preferences?

Theoretical Framework of the Study

Carl Jung's theory of psychological types, the foundation of the Myers-Briggs Type Indicator, asserts that seemingly random human behavior is actually orderly and consistent. This results from systematic differences in the way people perceive information and make judgments. Perceiving is the process used in becoming aware of

things, people, occurrences, and ideas. Judging includes the processes of coming to a conclusion about what has been perceived. Together, perception and judgment govern much of a person's behavior because perception determines what a person sees in a situation and judgment determines what the individual decides to do about it. "Thus, it is reasonable that basic differences in perception or judgment should result in corresponding differences in behavior" (Myers, 1980, p. 2).

In Jungian theory, perceiving is done in two distinct and contrasting ways. The first, sensing (abbreviated S), is how an individual becomes aware of things directly through the five senses. The second, intuition (N), is indirect perception using the unconscious to incorporate ideas or associations to perceptions acquired through sensing. That is, an individual perceives through his or her senses and also perceives things that never have been presented to his or her senses. Jung's theory suggests that the two types of perception compete for a person's attention and, through maturation and experience, one becomes preferred.

The preference of one over the other results in differing habitual patterns of behavior. Sensing types, when well developed, are generally more aware of the present experience, have acute powers of observation, and a good memory for facts and details. Lawrence (1984b) explained,

> Attitudes characteristically developed as a consequence of a preference for sensing include a reliance on experience rather than theory, a trust of the conventional and customary way of doing things, a preference for beginning with what is known and real, and then moving systematically, step by step, tying each new fact to past experience and testing it for its relevance in practical use. (p. 7)

Intuitive types also use sensing, but prefer intuition. This leads to a reliance on inspiration over experience, an interest in things novel and untried, and a preference for learning through the grasp of symbols and relationships. Myers and McCaulley (1985) explained,

> Intuition permits perception beyond what is visible to the senses, including possible future events. Thus, persons oriented toward intuitive perception may become so intent on pursuing possibilities that they may overlook actualities. They may develop the characteristics that can follow from emphasis on intuition and become imaginative, theoretical, abstract, future oriented, or creative. (p. 12)

A preference is also developed for one of two modes of judging, the way a person comes to conclusions. An individual in the thinking (T) mode uses logic to make judgments objectively, dispassionately, and analytically. The other mode, feeling (F), is of equal value and occurs when a person applies a personal, subjective value on things and weighs human factors and personal convictions when making a judgment. As in perceiving, one way of judging becomes preferred and, while both are used by an individual, one is relied upon more. This again leads to characteristic patterns of behavior, depending on the preference. Lawrence (1984b) explained:

> With good type development, expertise in thinking leads to powers of analysis and an ability to weigh facts objectively including consequences, unintended as well as intended. Attitudes typically developed from a preference for thinking include objectivity, impartiality, a sense of fairness and justice, and skill in applying logical analysis.
>
> Feeling leads to development of standards and values, and a knowledge of what matters most to themselves and other people. Feeling types typically develop an attitude for understanding people and a desire for affiliation, emphasis on harmony, and a capacity for warmth, empathy, and compassion. (p. 8)

The four combinations of perception and judgment, ST (sensing plus thinking), SF (sensing plus feeling), NT (intuition plus thinking), and NF (intuition plus feeling), "produce a different kind of personality, characterized by the interests, values, needs, habits of mind, and surface traits that naturally result from the combination" (Myers, 1980, p. 4).

Two other sets of preferences complete the picture of the Myers-Briggs types. The extraversion-introversion (EI) preference describes a person's tendency to focus on the inner world of concepts and ideas (introversion) or the outer world of people and things (extraversion). The extraverted attitude, when preferred, results in a desire to

act on the environment, an awareness and reliance on the environment for stimulation and guidance, and an action-oriented, sometimes impulsive way of meeting life. A person with the preference for introversion, on the other hand, may develop characteristics concerning clarity of concepts and ideas, reliance on enduring concepts more than on transitory external events, and a thoughtful, contemplative detachment from events (Myers & McCaulley, 1985, p. 13).

The final dimension, judgment-perception (JP), relates to a person's choice between the perceiving attitude and the judgment attitude as a way of dealing with the world outside oneself. This preference makes the difference between judging (J) people, who first attempt to order their lives, and the perceiving (P) people, who attempt to adapt to life. In the perceiving attitude, a person is open, curious, and attuned to incoming information. Persons who characteristically prefer the perceiving attitude seem in their outer behavior to be spontaneous, curious, and adaptable, open to new events and changes, and attempt to miss nothing. In the judging attitude, a person is concerned with making decisions, seeking closure, planning operations, or organizing activities. For persons who prefer the judging attitude, perception tends to be shut off as soon as they have observed enough to make a decision, and they often seem in their outer behavior to be organized, purposeful, and decisive (Myers & McCaulley, 1985, p. 14).

It was hypothesized that the dimensions of psychological type would be an important factor in troubleshooting behavior, particularly the EI, SN, and JP dimensions. Psychological type theory combined with empirical studies of troubleshooting behavior supports this hypothesis.

Standlee, Popham, and Fattu (1956) classified five methods of attack on electronic problems according to patterns of symptom perception, entertainment of

wrong hypotheses, perseverance, and redundancies, resulting in strategies having "differing degrees of efficacy" (p.103). Hunt and Rouse (1984) noted similar variations and defined two broad categories of behavior: fast, with minimal cognitive effort, and slow, with careful thought.

These patterns can be explained, in part, by type theory. Speed is an indicator of the introverted-extraverted preference. As Myers (1980) explained,

> Introverts can best deal with a situation by considering it an example of a reliable general principle; they are skilled at recognizing underlying principles. Extraverts deal with more situations, faster, and somewhat more casually and with less time out for reflection. They are faster, in part, because they already know more about the circumstances. (p. 119)

The sensing/intuitive preference is also an important factor. Sensing types prefer to apply standard ways of solving problems. They attend to practical and factual details and see specific things often overlooked by intuitive types. They are likely to be patient with routine details, but impatient when details get complicated. They are more likely to remember and apply rules to similar problems they have encountered in the past (Myers, 1980, p. 88).

Intuitive types, on the other hand, are more patient with complicated details and like solving new problems. They are generally adept at seeing patterns and meanings and following their hunches about the solution. Simple problems may not pose a sufficient challenge for this type, but a complex problem will exercise their intuitive preference (Myers, 1980, p. 88).

The judging/perceiving attitude is important due to its possible relationship to rigidity, defined by Bruner, Goodnow, and Austin (1956) as the "tendency to rely on familiar forms of groupings to explain unfamiliar or unexpected instances" (p. 111). Basically, it is the failure to associate new observations to alternative hypotheses and to alter troubleshooting strategies when needed. Brown and Burton (1986) wrote, "one

key to robust troubleshooting is the ability to improvise--to figure out the unusual, to recognize conflicting data, and to decide what should be discarded, and to know what to do when the appropriate instrument is not around" (p. 3). Morris and Rouse (1985a) added, "the strategic behavior of poor troubleshooters was characterized by incomplete and inappropriate use of information, ineffective hypothesis generation and testing, and generally less strategic flexibility" (p. 505).

According to Myers (1980), judging (J) types have the tendency to "live according to plans, standards, and customs not easily or lightly set aside, to which the situation of the moment must, if possible be made to conform" (p. 75). The judging types are usually self-regimented, purposeful, and exacting. "It is natural for a judging type to decide what is the best way of doing a thing, and then consistently do it that way" (Myers, 1980, p. 71).

Perceiving types, though, are generally more flexible. Among the perceivers' gifts is the ability to "live according to the situation of the moment and adjust themselves easily to the accidental and the unexpected" (Myers, 1980, p. 75). Also, perceiving types tend to have "a willingness to admit to consideration new facts, ideas, and proposals, even though they involve the reopening of decisions or opinions" (Myers, 1980, p. 72).

Anticipated Performance

If Myers-Briggs type preferences are consistent, characteristic patterns of behavior should have appeared in troubleshooting behavior. The results that were anticipated are summarized below.

The impulsive, action-oriented tendency for extraverted types contrasts with the reflective nature of introverted types, expected to result in less mean time to achieve a

solution for extraverted types. The introverted tendency for concentration, reflective observation, and reluctance to reveal thinking was expected to result in longer solution times for introverts.

The intuitive types were expected to have the advantage in mean times over sensing types due to the intuitive types tendency to conceptualize larger portions of a network and to establish relationships that sensing types may overlook. Also, sensing types generally spend more time gathering data than intuitive types.

Thinking types were anticipated to have a slight advantage in mean time over feeling types. Thinking types tend to favor logical and impersonal relationships like those found in the experimental network. Also, the thinking types tend to weigh cause and effect relationships more carefully than feeling types.

A shorter mean solution time was expected for judging types due to their tendency to drive toward completion and closure of tasks. Perceiving types are generally less conscious of time and prefer to explore alternatives.

With regards to the mean number of tests, the introverted types were expected to use fewer tests than extraverted types. The introverts, while expected to be slower than extraverts, are generally more thoughtful and careful than extraverts, resulting in fewer tests.

The intuitive types were expected to use fewer tests than sensing types. Intuitive types tend to see patterns and relationships in complex situations, while sensing types tend to get impatient when situations become complex.

Thinking types were expected to use fewer tests than feeling types due to the thinking types preference for logic. Thinking types are generally drawn to exercises like those used in the study that allow them to examine data and make a rational, calculated determination.

Perceiving types have been shown to be more willing to gather data and were expected to be more eager to perform a test to gain new information. Judging types have a tendency to want to be right and were expected to carefully consider a test before acting. Therefore, it was anticipated that the judging types would perform fewer tests.

Introverted types were expected to commit fewer errors than extraverts due to the extraverted types tendency to act quicker with less reflection. Also, introverted types like to consider things thoroughly before acting, while extraverted types have been shown to be more comfortable with trial and error methods for solving problems.

Sensing types are known to be impatient when details get complicated, so it was expected that the number of errors for sensing types would exceed the number of errors for intuitive types as problem complexity increased. Also, the sensing types preference to solve problems in standard, practiced ways was anticipated to lead to a greater number of errors, as the more complex problems required new and unpracticed approaches.

Although the difference was not expected to be large, thinking types were anticipated to have slightly fewer mean errors than feeling types. The thinking types preference for dealing with logical, impersonal relationships like those presented in the logic exercises were expected to give the thinking types a slight edge over feeling types.

It was anticipated that the perceiving types would commit a greater mean number of errors than judging types. The perceiving types tend to follow their impulses and generally want to miss nothing, while judging types have a tendency to want to be right.

For many of the same reasons discussed in previous sections, performance on the number of redundant tests was expected to be similar to the number of errors committed. Introverted types were expected to use fewer mean redundant tests than extraverted types, intuitive types were expected to use fewer mean redundant tests than

sensing types, thinking types were expected to use fewer mean redundant tests than feeling types, and judging types were expected to use fewer mean redundant tests than perceiving types.

Ultimately, it was expected that individuals with the preference combination of introversion, intuition, thinking, and judgment (INTJ) would perform the most effectively, that is, have the fewest number of tests, the fewest number of errors, the fewest number of redundant tests, and to take less time than most extraverted types to achieve a solution. People with INTJ type preferences are generally good at complicated problems and are apt to have insight, ingenuity, quick understanding, and fertility of ideas about problems (Myers, 1980, p. 92). They are stimulated by difficulty and generally are ingenious and resourceful in solving new and challenging problems.

In contrast, individuals with the preference combination of extraversion, sensing, feeling, and perceiving (ESFP), while able to achieve the correct solution, were expected to use more time, perform more tests with greater redundancy, and commit a greater number of errors. ESFP types are generally open-minded, flexible, and adaptable, leading to a tendency to be relaxed about assignments. They do not push to complete things because they enjoy the present moment and do not want to spoil it by undue haste or exertion (Myers & McCaulley, 1985, p. 25).

If troubleshooting performance relates to psychological type to a significant extent, the prospect is opened for devising instruction to help troubleshooters of all types improve their skills by way of research findings on the learning styles of the various MBTI types: group and psychomotor activities for extraverted types; individual work with emphasis on reading and verbal reasoning for introverted types; practical, step-by-step tasks that call for carefulness, thoroughness, and soundness of understanding for individuals with the sensing preference; tasks that call for

imagination, quickness of insight, and verbal fluency for intuitive types; formalized instruction with prescribed tasks calling for steady, orderly completion of tasks for trainees with the judging preference; and informal, discovery-type tasks for perceiving types (Lawrence, 1984a).

Knowledge of type preferences and links to behavior may also prove to be a valuable tool when expanding an individual's ability to use different psychological dimensions during stages of problem solving. Extraversion is called upon for acting; introversion for reflecting; sensing for gathering accurate and complete data; and intuition is relied upon for considering relationships and solution possibilities. Judgment helps the individual achieve an end to the problem, while perception is relied upon when openness and adaptability are essential.

Definitions of Terms

To clarify the language used in the study, terms are defined in the following section.

Electronic systems are an interconnected set of electronic components that process discrete, finite-valued signals.

An error is any test that fails to identify the faulty component or fails to gain information useful in identifying the fault. There are four types of errors: 1) a premature replacement, which occurs when more than one component exists in the feasible set and the wrong component is replaced; 2) an inferential error, when a component is tested that has an output that could have been inferred from a previous test; 3) an unnecessary test, which would occur when the feasible set has been reduced to a single component which is then tested; and 4) a test on a component in the nonfeasible set which could not logically or structurally belong to the feasible set.

Extraversion is the dimension of psychological type, according to Jung (1971), to orient mental processes on external objects and people.

A fault is a failure of one or more network components causing a system to malfunction.

Fault diagnosis is the determination of a malfunctioning component in a system through the application of tests.

Fault simulation includes the methods used to predict the behavior of an electronic system in the presence of a specified fault.

The feasible set is the set of components in the logic network that possibly contains the fault due to logical or structural relationships to the clues given.

Feeling is the dimension of psychological type concerned with reasoning and making judgments based on personal priorities and an appreciation of human values.

Intuition is the dimension of psychological type concerned with perception of meanings, relationships, and possibilities.

Introversion is the dimension of psychological type that focuses on inner thoughts and ideas.

Judgment is the dimension of psychological type characterizing the preference to live life in a self-regimented, purposeful, and exacting way.

The nonfeasible set is the set of components in the logic network that could not contain the faulty component due to structural or logical relationships.

Perception is the dimension of psychological type characterizing the preference to live life in a flexible, adaptable, and tolerant way.

For this study, problem solving is synonymous with fault diagnosis and troubleshooting.

A redundant test is a test on a component that has already been tested and has a known output.

Sensing is the dimension of psychological type that perceives the immediate, real, and practical side of life through the five senses.

For this study, system is a series of interrelated components representing an electronic network.

A test is a keyboard command to verify and display the output of a single component.

Thinking is the dimension of psychological type that reasons and makes judgments objectively, impersonally, and logically.

Troubleshooting is the process of diagnosing and localizing a malfunction in a network by observing symptoms and performing appropriate checks in a logical and systematic order.

Scope and Limitations of the Study

This study involved engineers and technicians who solved simulated logic problems. Limitations to this study were as follows:

1. The sample of 93 engineers and technicians used in this study was not representative of the general population. While the subjects' performance may not have represented the performance of the general population, stability of type preferences allows generalizations to similar samples of engineers and technicians.

2. There was concern over people indicating their "true" preferences on the Myers-Briggs Type Indicator. As Myers and McCaulley (1985) explained,

> As with any self-report instrument, the correctness of the results depends in part on how well the questions have been answered. If people answering the MBTI feel that they have nothing to gain, they may answer carelessly or even at random. If they fear they have something to lose, they may answer as they

> assume they should. But if they understand before answering that they will be told how they come out and will be invited to confirm or correct the report of their type, their answers are more likely to be genuine. (p. 53)

The Myers-Briggs Type Indicator was administered according to the instructions provided on the cover of the question booklets. The mechanics of instruction provided by Myers and McCaulley (1985, pp. 6-9) were also used.

3. Troubleshooting is a complex cognitive skill which does not lend itself to easy measurement or discovery of ideal or most efficient strategies. The simulation used explored only a small portion of the troubleshooting domain.

4. Intuitive types have been shown to be more adept than sensing types at conceptualizing abstractions like the exercises in this study. Intuitive types may have had an advantage over sensing types of grasping the concept of the displayed simulation. Scores on the initial problems may have been higher for intuitives while the sensing types "warmed up."

5. The relationship of troubleshooting performance on actual equipment to Myers-Briggs types was not measured.

6. Measurements were taken at various points in the work shift, with some individuals coming off a shift and others just beginning. Fatigue may have been a factor.

7. There were not sufficient numbers in certain categories of Myers-Briggs types to draw conclusions about whole types.

8. The majority of subjects in the sample were men (75%) and thinking types (65%), introducing at least two biases.

9. Data gathering was not typical of normal work-day procedures and subjects may have reacted to the measurement process.

10. The variable of intelligence among subjects may have been a factor in performance. While definitions of intelligence are dependent on context and application, overall measures of intelligence are distributed throughout the sixteen Myers-Briggs

types, resulting in the belief that intelligence was a randomized variable and did not influence performance.

Summary

Empirical studies have shown that electronic technicians demonstrate systematic patterns in behavior when troubleshooting complex systems. The Myers-Briggs Type Indicator, with Jung's theory of psychological types as a foundation, is a powerful tool for determining individual preferences for perceiving and acting. Relating psychological type to troubleshooting behavior may provide some insight to the mental processes used during troubleshooting and facilitate training in diagnostic problem solving.

This study was an attempt to identify and link patterns of troubleshooting behavior with Myers-Briggs types. A computer generated logic exercise that simulated simple electronic networks was used to present standard problems and record subjects' responses through the troubleshooting process. Time to solution, number of tests to solution, number of errors, and number of redundant tests were used as measures of performance. A link between performance measures and MBTI types would open a window to understand and improve performance of troubleshooters of all psychological types.

CHAPTER 2
REVIEW OF RELATED LITERATURE

This chapter is a summary of studies relevant to variations in fault diagnosis performance, efforts to relate problem solving performance to psychological type, and attempts to relate Myers-Briggs type preferences to learning styles. Three questions are addressed in this chapter: 1) How do variations in cognitive style or psychological type relate to patterns of troubleshooting performance? 2) What evidence suggests a link between Myers-Briggs type preferences and problem solving behavior? and 3) What differences in learning styles have been observed among individuals with different Myers-Briggs type preferences? The intent of this discussion is to relate observed problem solving variations to psychological type preferences. If a relationship exists, research linking psychological type and learning styles can be applied to enhance problem solving performance.

Consistent Patterns of Fault Diagnosis Performance

After World War II, the growing reliance on electronic systems and computers forced attention on the human processes used in troubleshooting and diagnosing equipment faults. By isolating the efficient strategies of effective troubleshooters, researchers hoped to streamline the training task and improve diagnostic and repair performance. As they observed technicians troubleshooting equipment, researchers noted four consistencies. First, certain variables were predictive of electronic troubleshooting performance. These included technical knowledge and experience; general reasoning ability; general and special aptitudes (manipulative, mechanical,

numerical, spatial, and visualization abilities); and personality characteristics related to accuracy, carefulness, attitudes, interests, motivation, rigidity, and speed. Second, individual patterns of problem solving were evident and related to problem perception, entertainment of wrong hypotheses, redundancy of tests, and perseverance. Third, more information could be obtained by examining the troubleshooting processes rather than products. And, fourth, there was a notable lack of understanding cognitive events occurring during troubleshooting, making it nearly impossible to explain and predict troubleshooting behavior (Standlee, Popham, & Fattu, 1956).

In a 1954 study, Saupe (in Morris & Rouse, 1985b) observed technicians repairing radio receivers and noted that poor troubleshooters had more incorrect hypotheses and pursued incorrect hypotheses longer than did good troubleshooters. They were also less likely to recognize critical information and tended to make fewer checks before accepting a hypothesis as correct. Saupe distinguished five types of overall methods of attack based on patterns of symptom perception, entertainment of wrong hypotheses, perseverance, and redundancies. Based on consistent performance, each technician could be assigned to one of five categories: logical, perseverant, cautious, persistent, or random.

Salz and Moore (in Morris & Rouse, 1985b), in a 1958 study of naval technicians troubleshooting shipboard systems, observed technicians who had been classified by their supervisors as either good or poor troubleshooters. The researchers noted several strategic hindrances affecting the poor troubleshooters. Ineffective troubleshooters consistently avoided difficult checks, made difficult checks when simpler checks would have been sufficient, made repeat checks needlessly, and omitted relevant checks.

Rasmussen and Jensen (1974) studied the troubleshooting behavior of six technicians on 45 actual problems in a nuclear research establishment. Using data gathered from recorded verbalizations of problem solving processes, the researchers noted that technicians tended to make rapid or impulsive decisions in their search for the fault based on individual perceptions and problem understanding. They noted that, "this, of course, gives a very individual pattern to the different overall procedures found in our cases" (p. 303).

McGuire and Babbott (1967) investigated the performance of individuals on clinical diagnoses and noted consistent patterns of behavior for each individual based on errors of commission (percentage of doing the wrong thing) and proficiency (percentage of doing the right thing). By plotting proficiency against error rate, they observed four clusters: constricted (low proficiency, low errors); random (low proficiency, high errors); shotgun (high proficiency, high errors); and discriminating (high proficiency, low errors).

Su and Govidaraj (1986) used a microcomputer-driven low fidelity simulation to train marine engineers in troubleshooting a ship's powerplant. A total of 28 subjects, all engineers familiar with marine powerplants, completed a set of 29 failures on the simulator. Su and Govidaraj discovered that the subjects could be categorized according to strategy employed: 1) a breadth-depth strategy, where subjects conducted a broad search for failed components and did a thorough check once a hypothesis was formed (a successful strategy); or 2) a balanced strategy, where subjects did not conduct a broad search but switched to a hypothesis evaluation stage although no obvious hypothesis was formed (an unsuccessful strategy). In their conclusion, the authors stated,

> Large individual differences were apparent between subjects. Although the trainees have very similar training on this particular system, they responded differently when presented with failures. It is conjectured that the way their experiences are organized and integrated with system knowledge might be

> responsible for the difference. In other words, the process in which the knowledge is organized might play an important role in how this knowledge is used. (p. 138)

As patterns of troubleshooting performance became increasingly evident, researchers attempted to link these patterns to cognitive styles or psychological attributes. Unfortunately, "data regarding the relationship between personality variables and individual differences in problem-solving are scarce" (Hunter & Levy, 1982, p. 379).

John (1957) investigated the problem solving behavior of 59 students from various class levels at the University of Chicago as they completed electronically operated logic exercises on the Problem Solving and Information (PSI) apparatus. The PSI involved determining the proper logical sequence of pushing buttons on the apparatus to illuminate a central panel light.

When John graphed the number of tests versus time he found a regularity of processes involved in the solution and stated, "it appears that individuals display different but highly characteristic rates of reaching decisions based on the evaluation of a body of data" (p. 296). He then attempted to correlate a number of psychological measures with performance and concluded that

> Correlation of certain of the variables [results] with other available measures show that personality factors such as anxiety, perceptual factors such as speed and flexibility of closure (Thurstone's Primary Mental Abilities), and cognitive factors, are all involved in problem solving performance. (p. 299)

Allen and Hays (1984) used 100 undergraduates to investigate the transfer ability from high, medium, and low fidelity equipment to actual equipment. They discovered consistent patterns in troubleshooting performance and applied Witkin's Group Embedded Figures Test (GEFT), Holland's Vocational Preference Inventory (VPI), and Bennett's Mechanical Comprehension Test (MCT) to the subjects. They discovered that field independent people (from the GEFT) have fewer incorrect solutions,

individuals with realistic interests (from Holland's VPI) attempt fewer tests, and people with strong mechanical comprehension (from the MCT) make fewer tests overall and are less likely to repeat a test. The authors concluded that "the relationship among strategies employed, individual differences, and the dependent variables (time to first solution, inter-response time, inter-test time, total time, number of tests, number of repeated tests, number of solutions, and number of solutions repeated) needs further exploration" (p. 20).

S. Rouse and W. Rouse (1982) concluded from their study of 60 technicians troubleshooting aircraft powerplants that "human performance in fault diagnosis tasks is related to cognitive style of the problem solver, particularly in terms of reflectivity-impulsivity" (p. 652). Subjects at the Institute of Aviation at the University of Illinois were given the Matching Familiar Figures Test, designed to measure the preference of reflectivity versus impulsivity. Additionally, Witkin's Group Embedded Figures Test was administered to identify the subjects' tendency toward field-dependence or field-independence. The findings were reported in detail in W. Rouse and Hunt (1984):

> Detailed statistical analyses of the cognitive style results were performed by partitioning trainees into impulsive and reflective groups, as well as field dependent and independent groups and using analyses of variance with dependent measures of errors, inefficiency and time. Our strongest conclusions: impulsives made significantly more errors, while reflective field independents were the best problem solvers. Superiority of field-independents tended to decrease as experience was gained, though. (p. 204)

The authors conjectured that the pattern recognition abilities of field-dependents required more time to adapt to new problem domains than field-independents. However, adaptation did eventually occur.

Hunt, Henneman, and W. Rouse (1981) gave the Embedded Figures Test (measuring field-dependence versus field-independence) and the Matching Familiar Figures Test (measuring impulsivity versus reflectivity) to 34 volunteers at the

Institute of Aviation. They then observed the volunteers' performance on locating a faulty component with a computer-simulated logic exercise. The authors found no difference in the overall performance of impulsives versus reflectives with respect to time, but impulsives made significantly more errors and were more inefficient with their use of tests. Field-dependents made more errors on initial trials but, after several sessions, their performance was essentially equivalent to field-independent types. The authors suggested that the pattern recognition abilities of field dependents require more adaptation time for new problems, but adaptation eventually occurs. On the other hand, practice can not compensate for effects of impulsivity.

Henneman and W. Rouse (1984) studied the relationship between impulsivity-reflectivity from the Matching Familiar Figures Test with performance on TASK and FAULT, computer-driven exercises involving the identification of a faulty component in a logic network. They found that "with regard to *a priori* predictors, the measures of cognitive style correlated at about the 0.4 level with TASK and FAULT performance" (p. 111). Their conclusion was that "independent dimensions of individual cognitive style and ability appear to be related to human fault diagnosis performance" (p. 111).

Moran (1986) investigated the performance of 74 apprentice electricians from Ireland on the relationship between field-dependence and field-independence and performance on isolating faults in an electrical circuit. She measured accuracy of symptom detection, the sequence of test points, diagnoses proposed, and the time to completion and found that field independence was correlated ($r = .76$, $p < .001$) with overall accuracy in fault diagnosis.

Relating Myers-Briggs types to fault diagnosis performance would be simplified if a definite link existed between field-dependence and field-independence and Myers-Briggs dimensions. Several researchers (Henderson & Nutt, 1980; Lusk & Wright,

1983; Thomas, 1983) have attempted to establish a link but none have succeeded. Lusk and Wright, in particular, found that "the sample size is of adequate size to detect a meaningful difference were one present. These results suggest that the two tests tap independent cognitive dimensions" (p. 1210).

While field-dependence and field-independence may involve different cognitive dimensions than the Myers-Briggs types, there is evidence that Myers-Briggs types display consistent behavior on solving problems other than fault-diagnosis types.

Myers-Briggs Types and Consistency of Performance in Problem Solving

Sachse (1981) categorized problem solving into four groups: puzzles, which include analogies, anagrams, and most games; component problems, which measure skills related to creative thinking; life skills, involving everyday problems such as making change, reading a map, and constructing a budget; and process problems, the simulations and troubleshooting exercises which were the focus of this study. Most of the research has examined the relationship between problem solving and Myers-Briggs types using puzzles and component problems. None have been identified regarding performance on fault diagnosis or process problems. However, there are generalizable results from many studies which help to support predictions of performance on process problems.

Yokomoto and Ware (1981) studied undergraduate students' performance on written examinations involving the analysis of linear circuits. They hoped to discover a relationship between the intuition function of the MBTI and performance on questions designed to require intuition. The authors attempted to support their theory that,

> In Jung's personality model, sensing and intuition are opposite processes by which people perceive. While each individual uses both, one is usually preferred. The degree of the preference in each individual varies. Sensing is the

> process of perceiving with the five senses, with a preference for facts and details, a trust in convention, and a preference to learn through experience.
>
> Sensing types are patient with details and generalize from the details to the big picture. Intuitives prefer to perceive through an intuitive grasp of meanings and relationship, see meanings in symbols, and think of possibilities. They have flashes of creativity, and they are comfortable with complexities but become bored with the mundane. Intuitives are referred to as global learners, preferring to look at the big picture before looking at details. (p. 305)

The examination scores were consistent with the types of questions (intuitive types scored higher on intuitive questions). Results were not significant, though, due to a small sample size.

Hunter and Levy (1982) explored the relationship between the MBTI and performance on the Embedded Figures Test and Dunker's Box Problem. The Embedded Figures Test involved tracing a simple figure embedded in a complex design whose organization conceals the outline of the simple figure. The goal of the Box Problem was to affix a candle to a wall given a candle, book of matches, pair of pliers, flashlight, and a box labeled "tacks" containing medium length tacks. As Hunter and Levy explained,

> On all performance measures but one, the Intuitive Perceptive (NP) types were predicted to surpass the others because they had tendencies to be more creative and less constrained by the concrete aspects of perceptual stimuli (intuitive) and to be more flexible and spontaneous (perceptive). The Sensing Judging (SJ) types' greater tendency to adhere to the concrete aspects of stimuli and established order would interfere in solving these problems. In listing the possible solution items, the Intuitive Judging (NJ) types were predicted to surpass the others, due to their tendencies to "see" beyond the literal aspects of stimuli (intuitive) and to be orderly, systematic, and persistent in tedious tasks (judging). (p. 380)

Consistent with the authors' predictions, the intuitive judging (NJ) types were able to list significantly more possible solutions to the Box Problem than other types ($p < .05$). In the Embedded Figures Test, the intuitive perceptive (NP) group attempted the most problems, while the sensing judging (SJ) types attempted the least number of problems ($p < .05$). Also, the NP types achieved significantly more correct answers than SJ types as hypothesized ($p < .05$).

Weber (1975) investigated the relationship between MBTI types and timed and untimed performance on French's Embedded Figures Test for 56 male and 56 female students at the University of Florida. He hypothesized that 1) introverted types would score higher than extraverted types; 2) intuitive types would score higher than sensing types; 3) thinking types would score higher than feeling types; 4) the combination of introversion, intuition, and thinking would produce the highest score; 5) judging types would produce more responses in time limited conditions; and 6) perceiving types would receive higher scores under open-ended conditions.

Two hypotheses were supported. One, intuitive types performed better than sensing types ($p < .01$ for timed tests, $p < .05$ for untimed tests), supporting the theory that intuitive types are generally more patient with complicated situations. Two, perceiving types scored higher ($p < .05$) on untimed tests than judging types, following the theory that judging types tend to be satisfied once they reach a judgment, while perceiving types prefer to remain open to new information as long as possible.

Caldwell (1965) used four types of problems to relate MBTI types and problem solving performance. The problems included a number strategy problem involving finding a matching number pair to associate with a given pair; a grid problem to copy a model drawing or design on a grid of four rows of four dots; a categorization problem, with the goal to react to a stimulus pattern with a variety of ideas; and maze tracing, involving finding the correct path through a series of 24 mazes. The types of problems, the type of behavior measured, and the hypothesized high and low performance types are summarized below.

TEST	BEHAVIOR	HIGH	LOW
1	Restructuring behavior	INTP	ISFJ
2	Exploratory behavior	ENFP	ESFP
2	Task persistence	ISFJ	ENTP
3	Ideational fluence	INFP	ESTP
4	Foresight	ISTP	INFP
4	Trial and error	ESFP	ISTJ

Although Caldwell found no significant differences between types on restructuring behavior and exploratory behavior, he did discover significant differences in other behaviors. First, the ISFJ types were more persistent than ENTP types (p < .05), consistent with MBTI theory. Second, INFP individuals were more ideationally fluent than ESTP types (p < .01), consistent with the theory that INFP types will tend to have a greater flood of ideas than ESTP types. And, third, ESFP types performed more trial and error than ISTJ types, explained by the goal-driven E attitude contrasting with the I attitude focusing on correctness and reluctance to reveal thinking.

Myers-Briggs Type Preferences and Learning Styles

In addition to differences in problem solving performance, contrasts in learning styles have been observed across the Myers-Briggs type preferences. McCaulley and Natter (1974) found that extraverts preferred learning in groups while introverts saw experiential training as unhelpful and were perceived as nonparticipating by other students. Extraverts tended to choose activities that involved a dialog with instructors and course monitors while introverts consistently chose supplementary lectures by an instructor.

Nisbet, Ruble, and Schurr (1982) examined 2100 high-risk students and found that sensing students showed difficulty in dealing with analogies, recognizing and interpreting figurative and symbolic language, recognizing relationships and establishing alternatives, and applying a new concept in any context beyond the original definitional model. Conversely, students with a preference for intuition disliked precise work with many details and often jumped to conclusions with errors of fact.

In studies summarized by Lawrence (1984a), sensing types preferred demonstrations, laboratories, computer-aided instruction, and audiovisual presentations. Sensing types enjoyed obtaining facts and preferred to work steadily and regularly toward completion of assigned tasks. Intuitive types found self-instruction helpful, liked courses that required self-initiative and self-paced learning, and enjoyed opportunities to exercise creative and original thinking for solving problems.

Thinking and feeling students have been observed to strongly differ in their acceptance of a T-group/laboratory model of instruction. The feeling students were perceived by other participants to be more involved in identifying group issues and helping the group work through the issues, while thinking types were seen as avoiding involvement in interpersonal issues (Lawrence, 1984a).

Feeling types have reported preferences for group projects (McCaulley & Natter, 1974) and human relations laboratories (McCaulley, 1978). Thinking types expressed a clear preference for more standard, instructor-directed lecture-discussion class. Thinking types also preferred structured courses with clear goals (Smith, Irey, & McCaulley, 1973).

The JP preference also has been observed to influence learning styles. Kilmann and Taylor (in Lawrence, 1984a) found no significant differences in T-group laboratory instruction but, when analyzing sociometric data, found that perceiving types were seen

as more effective in contributing to the overall group's progress, were more involved, and were credited with identifying issues and enlisting the group's aid in working through them. "Adaptability in managing emerging problems, a characteristic attributed to perceiving types in the theory, appears to be active and valued in this situation. The J's preference for pre-planned structure seems to work to their disadvantage in the laboratory instruction model" (p. 19).

Judging types preferred formalized instruction in traditional classroom structures with lectures, tests, teacher-directed requirements, a predictable routine, and emphasis on concrete thinking and memorization (Nisbet, Ruble, & Schurr, 1981). Judging types have shown a preference for self-study (Hoffman, Waters, & Berry, 1981) and logically programmed instruction from workbooks (McCaulley & Natter, 1974; Smith, Irey, & McCaulley, 1973).

In one of the few studies of aptitude-treatment interaction, Eggins (1980) explored concept attainment with sixth graders using three approaches to slide/tape science instruction: Bruner's inductive approach, Ausubel's advance organizer and didactic approach, and Gagne's highly structured, concrete-example design. With Bruner's model, intuitives learned best while sensing types were disadvantaged. Sensing types who were classified as field-independents by the Group Embedded Figures Test learned best with Gagne's approach, while field-independent sensing types scored best when taught by the advance organizer model.

The research clearly indicates the relationship between psychological type and preferences for instruction. Techniques and tools for applying this knowledge, though, are still scant for this "relatively new and rapidly growing area of research" (Myers & McCaulley, 1985, p. 130).

Summary

It is known from evidence on type behavior that general patterns of problem solving performance exist among the Myers-Briggs types. Extraverts tend to act quicker and with less reflection than introverts. Sensing types prefer to solve problems in standard practiced ways, in contrast to intuitive types who prefer to apply imagination in finding new ways of solving problems. Thinking types tend to apply logic and impersonal analysis in making decisions, different from feeling types who prefer to make decisions using a personal set of values. And judging types drive toward closure, acting quicker and with less information than perceptive types who generally will spend more time and acquire more information before moving toward a solution. These consistencies in type behavior, combined with evidence of regularities in problem solving performance among electronic technicians and other diagnosticians, brought about the expectation that some of the variation in problem solving behavior can be attributed to type preferences.

Individuals' type preferences can be be linked to learning processes. If psychological type preferences can be shown to influence problem solving behavior, the body of research relating type and learning styles can be applied to improve the training process for troubleshooters.

In addition to supporting the hypotheses, the literature review further substantiated the need for this study. First, consistent patterns of fault diagnosis performance among technicians have been empirically shown. Second, problem solving performance on fault diagnosis tasks has been linked to other dimensions of cognitive styles, primarily Witkin's field-dependence and field-independence model. And, third, consistency of performance among Myers-Briggs types has been demonstrated on a variety of problem types other than process problems. These findings pointed to the

expectation that there would be a relationship between Myers-Briggs types and performance on fault diagnosis tasks. Apparently, no one had explored that relationship.

CHAPTER 3
METHODOLOGY

The experimental procedures for the study are described in this chapter. The discussion includes the methods used to select subjects, gather data, and analyze the results. The two primary instruments used in this investigation were the Myers-Briggs Type Indicator, Form G and a computer-driven troubleshooting exercise. The history and validity of the instruments are also examined.

Description of the Subjects

The independent measures of psychological type preferences, from Form G of the Myers-Briggs Type Indicator, were available for 105 engineers and technicians employed in the maintenance of ground electronics at the Kennedy Space Center in Florida. Each subject's sex, age, and highest school grade completed were also available. Of the 105 subjects, 90 completed the problem solving exercise; six subjects refused and nine subjects were not able to complete the exercise.

The results for the type distribution are shown in Table 3-1, with whole type, number of subjects per type, and percentage of total sample. Distributions of age, grade achieved, and years of electronic experience are shown in Tables 3-2, 3-3, and 3-4, respectively.

The 90 subjects were volunteers and represented a good cross-section of the approximately 400 electronic engineers and technicians involved in electronic equipment maintenance at the Kennedy Space Center. Of the 90 subjects with valid responses, 70 (75%) were male.

Table 3-1 Type Distribution of
90 Engineers and Technicians

ISTJ	ISFJ	INFJ	INTJ
17	5	3	9
18.8%	5.5%	3.3%	10.0%
ISTP	ISFP	INFP	INTP
9	2	1	7
10.0%	2.2%	1.1%	7.8%
ESTP	ESFP	ENFP	ENTP
2	3	3	7
2.2%	3.3%	3.3%	7.8%
ESTJ	ESFJ	ENFJ	ENTJ
11	3	2	6
12.2%	3.3%	2.2%	6.7%

Table 3-2 Age Distribution of
90 Engineers and Technicians

Age Range	Number	Percentage
20-24	3	3.3%
25-29	29	32.3%
30-34	17	18.9%
35-39	11	12.2%
40-44	10	11.1%
45-49	11	12.2%
50-54	4	4.5%
55-59	3	3.3%
60-65	2	2.2%

Table 3-3 Distribution of Highest Grade Completed for 90 Engineers and Technicians

Highest Grade Achieved	Number	Percentage
<12	1	1.1%
12	29	32.2%
13	8	8.9%
14	22	24.4%
15	7	7.8%
16	18	20.0%
16+	5	5.6%

Table 3-4 Distribution of Years of Electronic Experience for 90 Engineers and Technicians

Years	Number	Percentage
0-1	8	8.9%
2-4	12	13.3%
5-7	10	11.1%
8-10	15	16.7%
11+	45	50.0%

Instrumentation

The MBTI is a 126-item dual response inventory that measures preferences along the four dimensions discussed in Chapter 1. First published by the Educational Testing Service in 1962, the MBTI has a rich history of development, validation, and use in the areas of psychology, medicine, and education. The MBTI has been continuously refined and proven valid and reliable (Myers & McCaulley, 1985).

Test-retest reliabilities of the MBTI show consistency over time, with reliability in the proportion of cases assigned to the same preference after retest, the proportion of cases reporting all four preferences the same after retest, and the correlation of continuous scores for each preference type.

The MBTI has been shown to be valid when correlated with instruments that measure similar psychological constructs. Also, there is a large amount of evidence to suggest that the MBTI measures are consistent with Jung's theory and with Briggs' and

Myers' expansion of Jung's writings. At least 250,000 responses to the MBTI have been obtained and analyzed during development of the instrument with results discussed extensively in Myers and McCaulley (1985).

The troubleshooting exercise is modeled after W. Rouse's TASK (Troubleshooting by Application of Structural Knowledge), well described in the literature (Henneman & Rouse, 1984; Hunt & Rouse, 1981; Rouse & Hunt, 1984; Rouse & Rouse, 1982). TASK was specifically designed to explore and measure context-generic troubleshooting strategies. Over 300 subjects, most of them involved in aircraft and electronics systems maintenance, have solved over 24,000 fault diagnosis problems with TASK. Studies with TASK have included investigations regarding transfer of training, forced pacing, problem size, effects of computer aiding, and performance of subjects relative to psychological dimensions of field-dependence/field-independence and reflectivity/impulsivity.

The exercise was selected because it met the criteria suggested by John (1957) for investigating problem solving behavior:

> The ideal format for observation of the problem solving process should start the subject with a standard minimum of information about a problem and then require him to structure his own presolution behavior with a minimum of externally imposed constraint. Such a format should be based on a task that is maximally free of special skills, special knowledge, or experiences peculiar to a given culture. Familiarity with the task should be minimal. (p. 3)

The exercise used in this study is similar to TASK with a few enhancements. The enhancements include revised instructions, a sharper display, quicker presentation of subsequent problems, and a performance summary for the subject at the conclusion of the exercise. It was believed that the enhancements simplified use of the instrument without affecting its validity or reliability.

The exercise was written in the BASIC programming language and ran on an IBM Personal Computer AT with a monochrome monitor and a keyboard. A troubleshooting problem began with the display of a logic network, as shown in Figure 3-1.

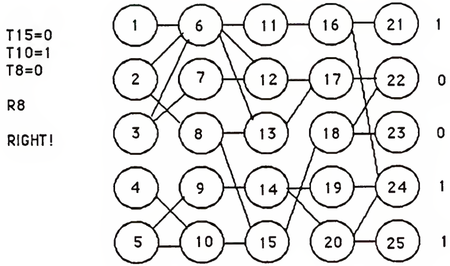


Figure 3-1
An Example of a Logic Exercise

The subject's task was to test connections between components until a single failed component was found. A component was like a logical "and" gate and produced a value of 1 if all inputs to the component carried values of 1, and the component had not failed. If a component failed, it produced values of 0 on all the outputs from it. Any components that were reached by these outputs would in turn produce values of 0. This process continued and the effects of a failure were propagated through the network, evidenced by the 0 output(s) on the right side of the network.

The program tracked the time to solution, the number of tests to achieve the solution, the number of errors, and the number of redundant tests or replacements. A written report and an electronic transaction file were generated for each problem which included the four performance measures and the sequence of tests and replacements. Problems increased in complexity by adding more components and more connections between components.

To test a component, the subject used the keyboard to specify a component and display its output. The output of the component was displayed (1 if good, 0 if bad). To replace a component, the desired component was selected with keyboard commands. Subjects were given feedback about the correctness of their choice, and, when the faulty component was identified, the next problem was displayed. At the conclusion of the exercise, a summary was given to the subject showing time to solution, number of tests, number of errors, and number of redundancies.

In the example shown in Figure 3-1, component 15 was tested first and shown to have a bad output (0 output). Component 10 was then tested and proved good. Finally, component 8 was verified to have a faulty output. Since the only input to component 8 is component 2, and component 2 has other outputs leading to good components (evidenced by the good output at component 21), the subject concluded that component 8 was defective, replaced it, and was told that component 8 was the correct answer.

Performance measures of time to solution, number of errors, number of tests, and number of redundant tests were selected for this study based on previous studies using TASK (Henneman & Rouse, 1984). Also, Gagne (1964), from earlier work with electronic technicians, suggested, "when the problem is one requiring a sequence of steps, as in the case with troubleshooting, number of incorrect moves, number of irrational moves, or number of redundant moves are all possible error measures" (p. 297).

Field Procedures

Each subject was individually administered five troubleshooting problems of increasing complexity, using an IBM Personal Computer for display of the instructions and problems. An administrator unfamiliar with the subject's psychological type provided a brief personal orientation and helped the subject initiate the exercise. The

computer screen presented a standard introduction for the exercise (see Appendix A). The administrator then observed the subject complete a sample exercise and verified correct performance and understanding of "and" gate functions.

After completion of the five problems (see Appendix B), the subject completed a questionnaire (see Appendix C) to gather data regarding experience and to assess opinions toward the exercise. This tested for any affective interference in the problem performances.

Data Collection and Analysis

Each data record included the following:

Myers-Briggs Type Preferences and Preference Points

Age

Years of School

Years of experience in electronics

Sex

Number of problems successfully solved

	PROBLEM	1	2	3	4	5	TOTAL
Time to solution							
Number of tests							
Number of errors							
Number of redundant tests							

With the Myers-Briggs type preferences and each subject's age, sex, number of years experience, and highest grade achieved as the independent variables and the measures of troubleshooting performance as dependent variables, statistical runs were made on the IBM 4311 computer at the computer center at the University of Central Florida using the Statistical Package for the Social Sciences (SPSS). Analyses depended

on the hypothesis to be tested and included t-tests and Pearson product-moment correlations. The analyses suggested intercorrelations between variables, resulting in post-hoc analyses using multiple regression and partial correlation analysis. Results are discussed in Chapter 4.

Summary

Ninety engineers and technicians individually completed five problems of increasing difficulty using an IBM PC microcomputer to display the problems and record subjects' responses. Time to solution, number of tests and replacements, number of errors, and number of redundant tests were tracked as performance measures.

The performance measures were analyzed against independent variables of the four dimensions of Myers-Briggs type preferences and other independent variables of age, sex, years of education, and years of experience in electronics. Multiple regression analysis, t-tests, and Pearson product-moment correlations were used to determine which independent variables were influencing problem solving behavior. Results are summarized and discussed in Chapter 4.

CHAPTER 4
RESULTS

The attempt of this study was to determine the relationship between fault diagnosis problem solving performance and Myers-Briggs type preferences. To do so, a computer-driven logic exercise, modeled after Rouse's TASK, was used to record subjects' performance with respect to time to solution, number of tests to solution, number of errors, and number of redundant tests.

Expectations of performance were based on differences in individuals along the four dimensions of the Myers-Briggs type preferences. Extraverted types were expected to require less time, to perform more tests, to commit a greater number of errors, and to perform more redundant tests than introverted types. Intuitive types were expected to be quicker to solution, require fewer tests, commit fewer errors, and perform fewer redundant tests than sensing types. Thinking types were expected to use less time and fewer tests and commit fewer errors and redundancies than feeling types. The judging-perceiving preferences were also expected to affect performance, with judging types using less time and fewer tests, and committing fewer errors and fewer redundant tests than perceiving types.

Although few differences were supported to levels of statistical significance ($p < .05$) using one-tailed t-tests, performance differences were largely as expected from Myers-Briggs theory. Introverted types used fewer tests and committed fewer errors with fewer redundant tests than extraverted types. Intuitive types used less time

with fewer tests, fewer errors, and fewer redundancies than sensing types. Thinking types used less time, performed fewer tests, and committed fewer errors than feeling types.

However, several results were not anticipated. Extraverted types used more time to achieve a solution than introverted types. And perceiving types outperformed judging types on every measure of the problem solving task.

Performance Measures

Descriptive and inferential statistics for the performance measures are presented in this section. Statistical inferences for the relationships between performance measures and psychological types are based on one-tailed t-tests with a significance level of .05.

Minimum Time to Solution

Figures 4-1 through 4-4 show the results for mean time to solution for the EI, SN, TF, and JP type preferences, respectively. As shown in Figure 4-1, individuals with the extraverted preference generally used a greater amount of mean time (m = 847.67 sec) to solve the problem than introverted types (m = 785.00 sec). However, the difference in time to solution between extraverts and introverts was not statistically significant ($t(88) = 0.55$, $p = .58$).

Figure 4 2 shows the results for mean times to solution for sensing and intuitive types. Sensing types consistently took longer (m = 876.15 sec) to achieve the solution than intuitive types (m = 724.58 sec). While consistent with expected performance, the difference in mean time was not significant to the .05 level ($t(88) = 1.47$, $p = .07$).

Results for the TF type preferences are shown in Figure 4-3. As expected, thinking types used less mean time (m = 745.56 sec) to solve the problems than feeling

types ($\underline{m}$ = 1018.00 sec). Though the difference in mean time for the TF preferences approached significance at the .05 level, the difference was not statistically significant ($\underline{t}(88) = 1.60$, $\underline{p} = .06$).

Figure 4-4 shows the mean time to solution for the JP type preferences. Contrary to expectations, perceiving types used less total time ($\underline{m}$ = 772.73 sec) than the judging types ($\underline{m}$ = 836.09 sec). The difference in mean time for the JP type preferences was not statistically significant ($\underline{t}(88) = 0.51$, $\underline{p} = .59$).

Minimum Number of Tests

The performance of EI preferences with respect to number of tests is illustrated in Figure 4-5. As expected, introverted types used fewer mean tests ($\underline{m} = 39.3$) than extraverted types ($\underline{m} = 42.0$). The difference in mean number of tests for the EI preferences was not statistically significant ($\underline{t}(88) = 0.85$, $\underline{p} = .40$).

Figure 4-6 illustrates the mean number of tests used by individuals with the SN type preferences. As expected, individuals with the intuitive preference used fewer tests ($\underline{m} = 36.4$) than sensing types ($\underline{m} = 43.5$), with a significant difference for the mean total number of tests ($\underline{t}(88) = 2.31$, $\underline{p} < .05$).

Differences in mean number of tests used for individuals with the T or F preference are shown in Figure 4-7. As expected, thinking types used fewer mean tests ($\underline{m} = 39.8$) than feeling types ($\underline{m} = 42.5$), though the difference in mean number of tests was not statistically significant ($\underline{t}(88) = 0.75$, $\underline{p} = .46$).

Differences in number of tests for the JP type preferences are shown in Figure 4-8. Judging types were expected to use fewer mean tests ($\underline{m} = 42.3$), but perceiving types actually used fewer mean tests ($\underline{m} = 37.6$). Using a one-tailed t-test, this difference was determined be statistically significant ($\underline{t}$ (88) = 1.70, $\underline{p} < .05$).

Minimum Number of Errors

Figures 4-9 through 4-12 indicate the performance of the different type preferences with respect to minimum number of errors. Once again, the direction of the predictions were largely supported except for the JP type preferences, where perceiving types committed a fewer number of mean errors than judging types.

As shown in Figure 4-9, introverted types made fewer errors (m = 11.5) than extraverted types (m = 11.8). Though the outcome was consistent with expected performance, the difference was small and not statistically significant ($t(88) = 0.17$, $p = .87$).

The differences in mean error performance for sensing types versus intuitive types are shown in Figure 4-10. As expected, individuals with the intuitive preference committed fewer mean errors (m = 9.6) than individuals with the sensing preference (m = 13.1). This difference was determined to be statistically signficant ($t(88) = 2.28$, $p = .01$).

The performance of mean number of errors for TF preferences is illustrated in Figure 4-11. As expected, thinking types committed fewer total mean errors (m = 11.2) than feeling types (m = 13.1), though the difference was not statistically significant ($t(88) = 0.99$, $p = .32$).

Performance for the JP type preferences for mean number of errors is shown in Figure 4-12. Contrary to expectations, perceiving types committed fewer mean errors (m = 10.3) than judging types (m = 12.5). The difference in mean number of errors for the JP type preference was not statistically significant ($t(88) = 1.46$, $p = .07$).

Mean Number of Redundant Tests

Differences between the type preferences on the use of redundant tests were largely as anticipated, though the values for the performance measures were smaller

than expected. Overall, subjects did not use many redundant tests, probably due to the test outcomes remaining on the computer screen for each problem. Subjects generally realized that a retest was unnecessary. Nevertheless, there was a difference in performance levels as shown in Figures 4-13 through 4-16, with a significant difference in total number of redundant tests for individuals with the EI type differences and the JP type differences. Also, as shown in Figure 4-16, perceiving types committed fewer mean redundant tests than judging types, contrary to expectations.

The differences in performance between EI type preferences and number of redundant tests are shown in Figure 4-13. Extraverted types used almost three times as many redundant tests (m = 1.1) as introverted types (m = 0.4), a statistically significant difference ($t(88) = 2.19$, $p = .04$).

Figure 4-14 shows the mean number of redundant tests used by individuals with the sensing or intuitive type preference. As expected, intuitive types committed fewer redundancies (m = 0.4) than sensing types (m = 0.9), though the difference in performance was not statistically significant ($t(88) = 1.43$, $p = .08$).

The relationship between mean number of redundant tests and the TF type preferences is shown in Figure 4-15. There was no difference between TF types for this performance measure (m = 0.7).

Judging and perceiving types performed differently with respect to the mean number of redundant tests as shown in Figure 4-16. Contrary to expectations, perceiving types used fewer redundant tests (m = 0.4) than judging types (m = 0.9), a statistically significant difference ($t(88) = 1.94$, p =.03).

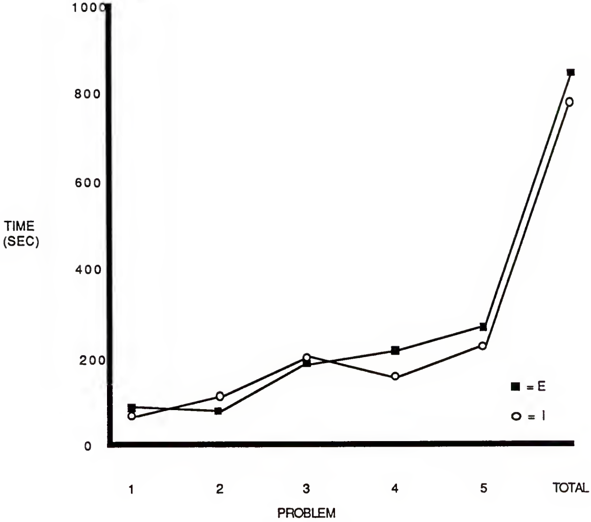


Figure 4-1
Mean Time to Solution
for EI Type Preferences

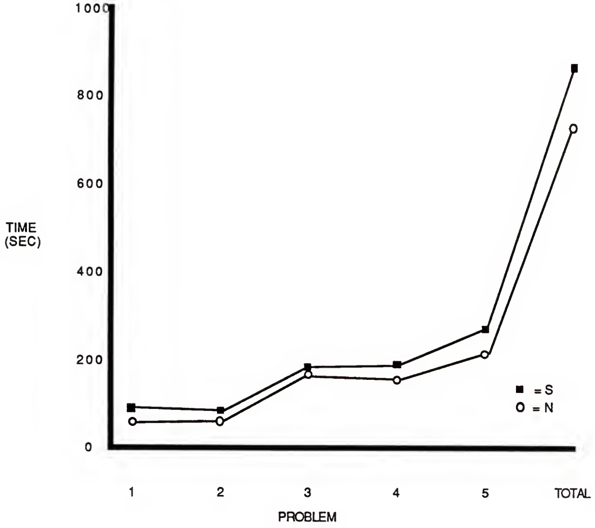


Figure 4-2
Mean Time to Solution
for SN Type Preferences

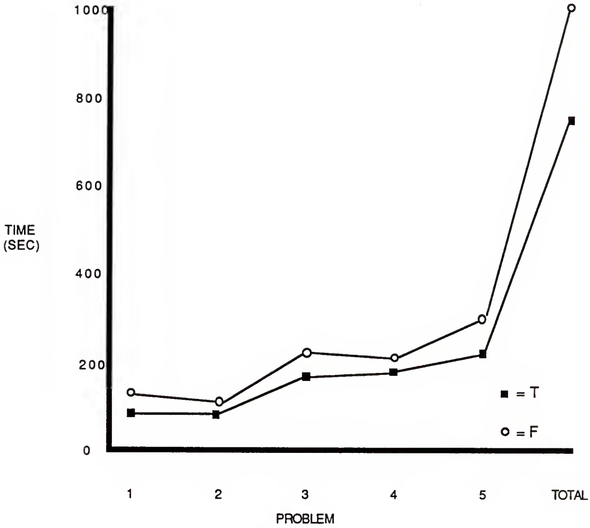


Figure 4-3
Mean Time to Solution
for TF Type Preferences

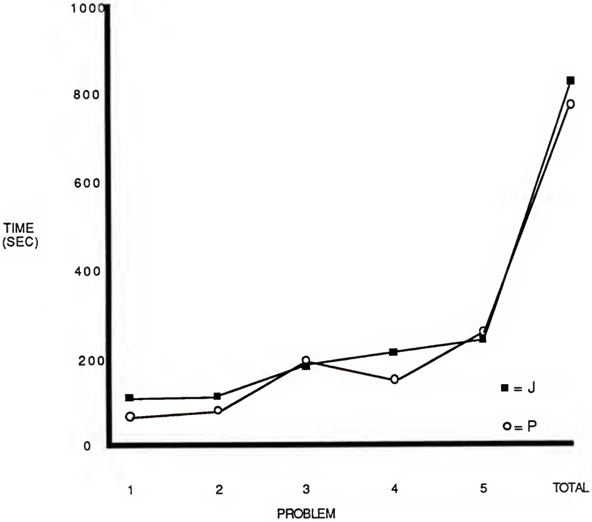


Figure 4-4
Mean Time to Solution
for JP Type Preferences

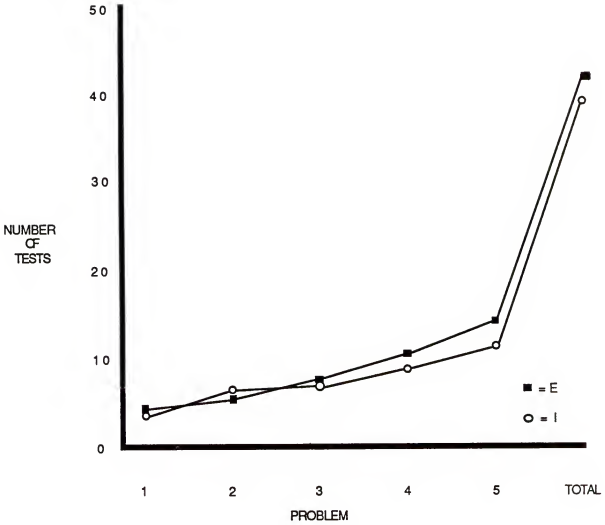


Figure 4-5
Mean Number of Tests
Performed for EI Type Preferences

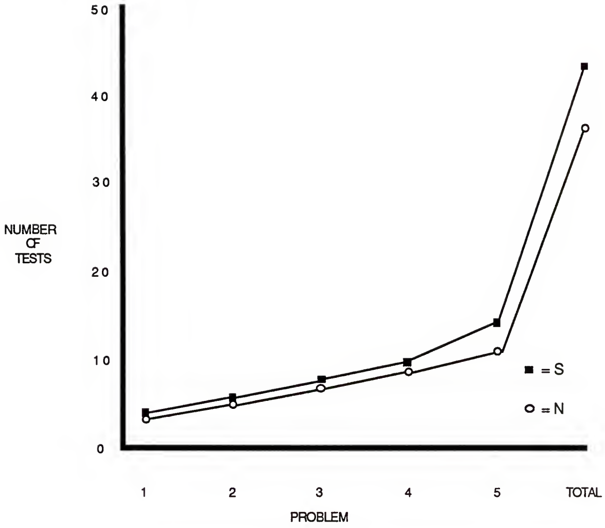


Figure 4-6
Mean Number of Tests
Performed for SN Type Preferences

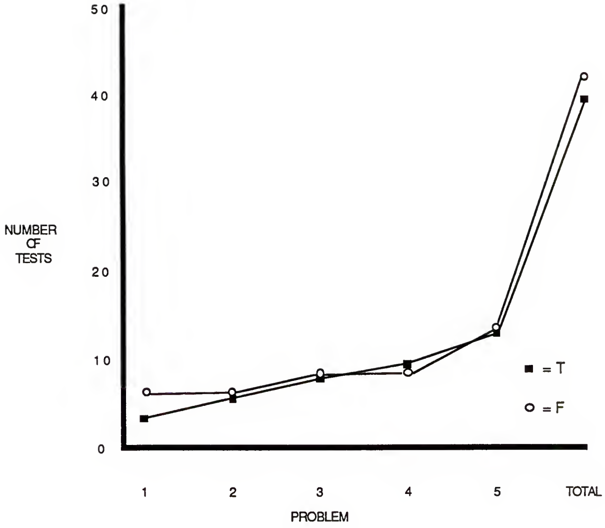


Figure 4-7
Mean Number of Tests
Performed for TF Type Preferences

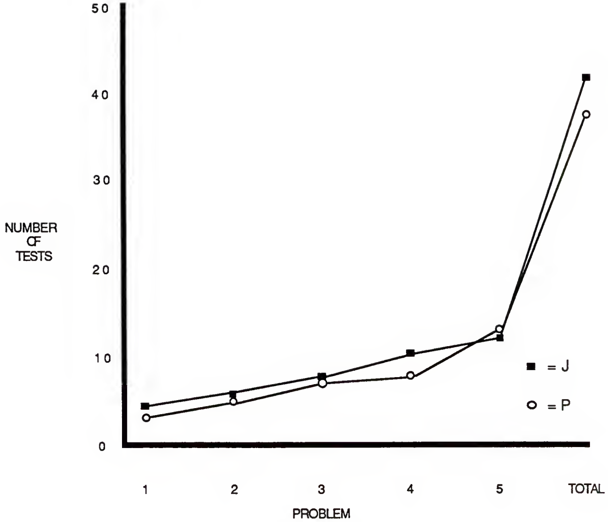


Figure 4-8
Mean Number of Tests
Performed for JP Type Preferences

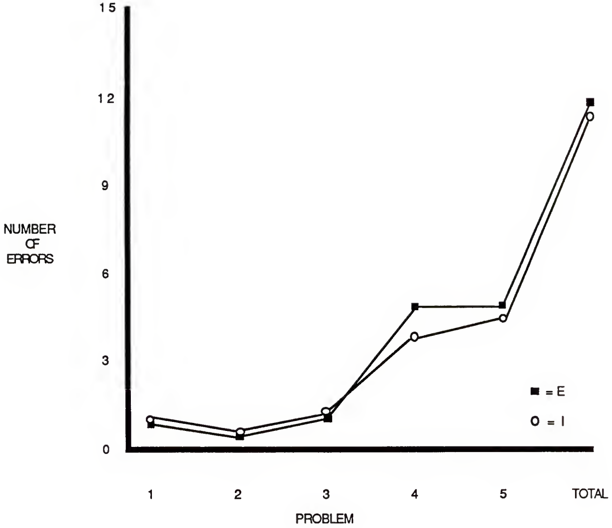


Figure 4-9
Mean Number of Errors
for EI Type Preferences

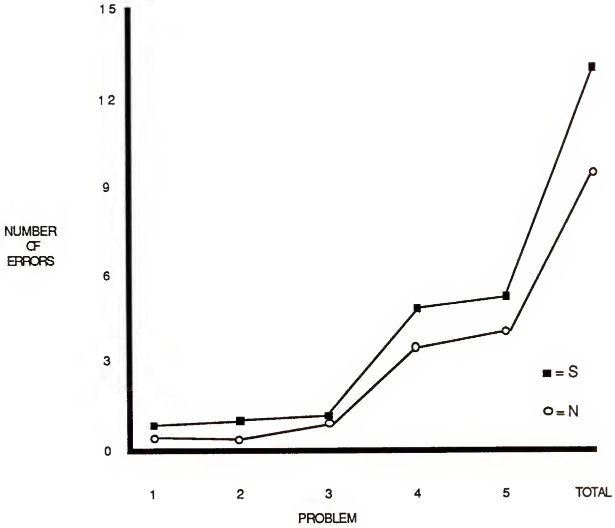


Figure 4-10
Mean Number of Errors
for SN Type Preferences

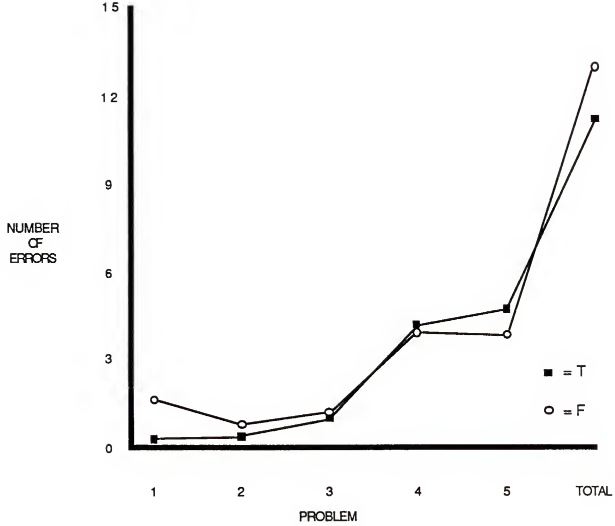


Figure 4-11
Mean Number of Errors
for TF Type Preferences

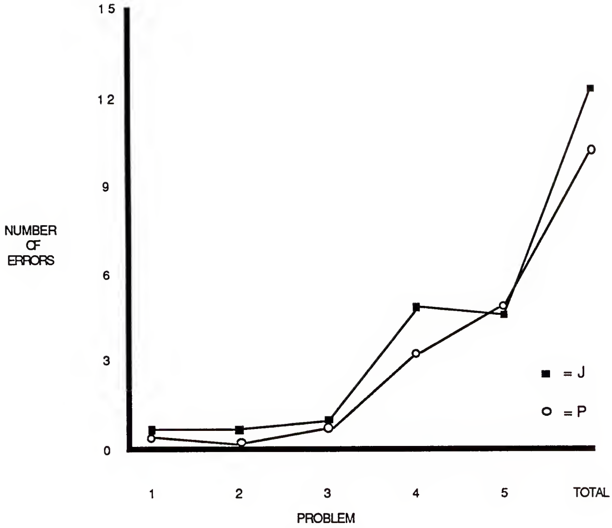


Figure 4-12
Mean Number of Errors
for JP Type Preferences

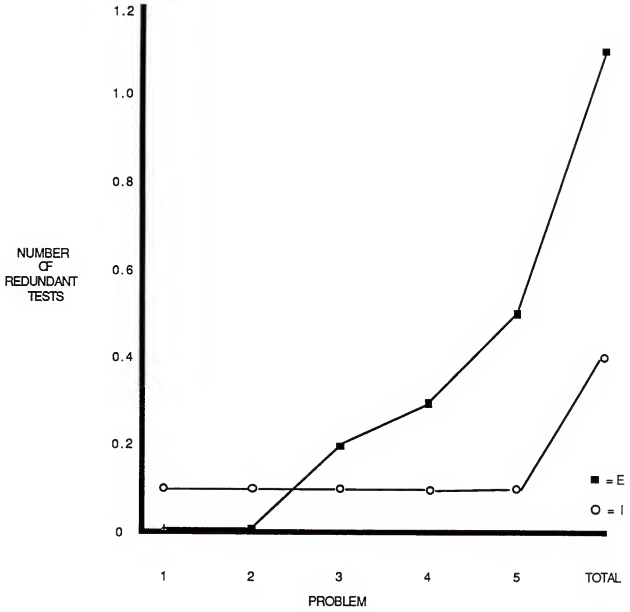


Figure 4-13
Mean Number of Redundant
Tests for EI Type Preferences

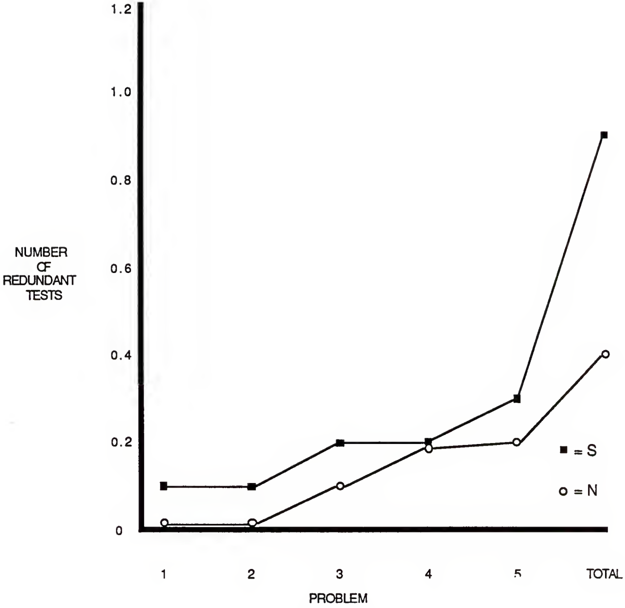


Figure 4-14
Mean Number of Redundant
Tests for SN Type Preferences

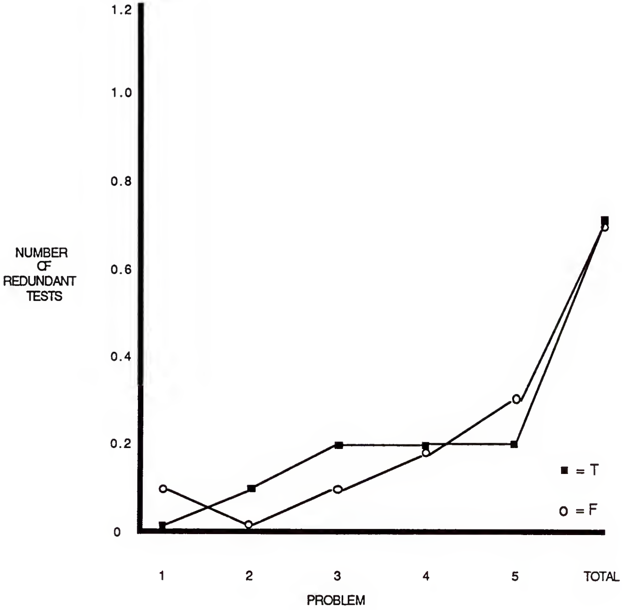


Figure 4-15
Mean Number of Redundant
Tests for TF Type Preferences

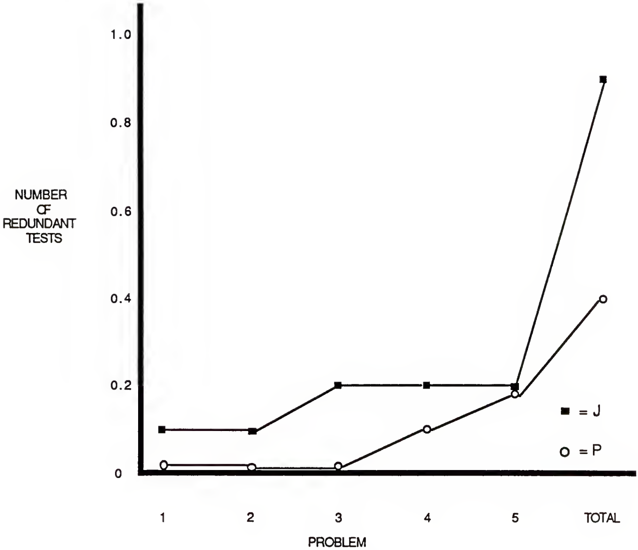


Figure 4-16
Mean Number of Redundant
Tests for JP Type Preferences

Total Measures of Performance

Total measures of performance for each of the type preferences are summarized in Table 4-1. Although differences were largely as expected, one-tailed t-tests indicated only a small number of differences with statistical significance at the .05 level.

Table 4-1
Overall Measures of Problem Solving Performance for Myers-Briggs Type Preferences

Type Preference	Mean Total Time to Solution (sec)	Mean Total Number of Tests	Mean Total Number of Errors	Mean Total Number of Redundant Tests	
Extravert (E)	847.67	42.0	11.8	1.1*	(n=39)
Introvert (I)	785.00	39.3	11.5	0.4*	(n=51)
Sensing (S)	876.15	43.5*	13.1*	0.9	(n=52)
Intuition (N)	724.58	36.4*	9.6*	0.4	(n=38)
Thinking (T)	745.56	39.8	11.2	0.7	(n=68)
Feeling (F)	1018.00	42.5	13.1	0.7	(n=22)
Judging (J)	836.09	42.3*	12.5	0.9*	(n=56)
Perceiving(P)	772.73	37.6*	10.3	0.4*	(n=34)

* denotes a significant difference between means ($p < .05$) N=90

Analyses of Hypotheses

In this section, the hypotheses are restated and analyzed with the performance data. Hypotheses A through D deal with expected outcomes of performance measures with subjects grouped by type preferences. Hypotheses E through H are an analyses of performance measures with independent variables of age, years of experience, years of education, and sex, respectively.

Hypotheses A: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by psychological type preferences, the following results are anticipated for mean time needed to identify the faulty component:

1. When individuals are grouped according to the extraversion-introversion preference, extraverted types will use less mean time to identify the faulty component than introverted types ($p < .05$).

This hypothesis was not supported by the findings. Actually introverted types used less mean time ($m = 785.00$) to identify the faulty component than extraverted types ($m = 847.67$), though the difference was not statistically significant ($t(88) = 0.55$, $p = .58$).

2. When individuals are grouped according to the sensing-intuition preference, intuitive types will use less mean time to identify the faulty component than sensing types ($p < .05$).

Intuitives did use less mean time ($m = 724.58$) to identify the faulty component than sensing types ($m = 876.15$), though the hypothesis was not supported to the required level of statistical significance ($t(88) = 1.47$, $p = .07$).

3. When individuals are grouped according to the thinking-feeling preference, thinking types will use less mean time to identify the faulty component than feeling types ($p < .05$).

Thinking types used less mean time ($m = 745.56$) to identify the faulty component than feeling types ($m = 1018.00$), but the hypothesis was not supported to the required level of statistical significance ($t(88) = 1.60$, $p = .06$).

4. When individuals are grouped according to the judging-perceiving preference, judging types will use less mean time to identify the faulty component than perceiving types ($p < .05$).

Contrary to the hypothesis, perceiving types used less mean time (m = 772.73) to identify the faulty component than judging types (m = 836.09), though the difference was not signficant ($t(88) = 0.51$, $p = .59$). This hypothesis was not supported.

Hypotheses B: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by psychological type preferences, the following results are anticipated for the mean number of tests needed to identify the faulty component:

1. When individuals are grouped according to the extraversion-introversion preference, introverted types will use fewer mean tests to identify the faulty component than extraverted types ($p < .05$).

Introverted types did use fewer mean tests (m = 39.3) than extraverted types (m = 42.0), though the difference was not statistically significant ($t(88) = 0.85$, $p = .40$). This hypothesis was not supported.

2. When individuals are grouped according to the sensing-intuition preference, intuitive types will use fewer mean tests to identify the faulty component than sensing types ($p < .05$).

This hypothesis was supported to the required level of statistical significance. As expected, intuitive types used fewer tests (m = 36.4) than sensing types (m = 43.5), $t(88) = 2.31$, $p < .05$. Intuitive types were expected to be more adept at relating meanings to gathered facts than sensing types.

3. When individuals are grouped according to the thinking-feeling preference, thinking types will use fewer mean tests to identify the faulty component than feeling types ($p < .05$).

Thinking types used fewer mean tests (m = 39.8) than feeling types (m = 42.5), though this hypothesis was not supported to the required level of statistical significance ($t(88) = 0.75$, $p = .46$).

4. When individuals are grouped according to the judging-perceiving preference, judging types will use fewer mean tests to identify the faulty component than perceiving types ($p < .05$).

This hypothesis was not supported. Actually, perceiving types used significantly fewer mean tests than judging types. Perceiving types apparently applied their adaptability to these types of problems, resulting in more flexible solution strategies and fewer tests (m = 37.6) than judging types (m = 42.3), $t(88) = 1.70$, $p < .05$. The judging types, though expected to use fewer tests than perceiving types because of their tendency to want to be right, may have used more tests because they wanted each test to be right and were less concerned with finding the most efficient solution strategy. Striving for efficiency, on the other hand, is a characteristic of perceiving types.

Hypotheses C: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by psychological type preferences, the following results are anticipated for the mean number of errors committed while identifying the fault:

1. When individuals are grouped according to the extraversion-introversion preference, introverted types will commit fewer mean errors while identifying the faulty component than extraverted types ($p < .05$).

Introverted types had fewer mean errors (m = 11.5) than extraverted types (m = 11.8), but the hypothesis was not supported to the required level of statistical significance ($t(88) = 0.17$, $p = .87$).

2. When individuals are grouped according to the sensing-intuition preference, intuitive types will commit fewer mean errors while identifying the faulty component than sensing types ($p < .05$).

This hypothesis was supported; intuitive types committed significantly fewer mean errors ($m = 9.6$) than sensing types ($m = 13.1$), $t(88) = 2.28$, $p = .01$. Individuals with the preference for intuition committed fewer errors when testing, probably due to their tendency to piece together known facts to a larger picture, in this case, the suspected fault. This suggests that intuitive types may be more adept than sensing types at differentiating between the feasible and nonfeasible set of logic components.

3. When individuals are grouped according to the thinking-feeling preference, thinking types will commit fewer mean errors while identifying the faulty component than feeling types ($p < .05$).

Thinking types had fewer errors ($m = 11.2$) than feeling types ($m = 13.1$), but the hypothesis was not supported to the required level of statistical significance ($t(88) = 0.99$, $p = .32$).

4. When individuals are grouped according to the judging-perceiving preference, judging types will commit fewer mean errors while identifying the faulty component than perceiving types ($p < .05$).

This hypothesis was not supported. Actually, judging types committed more mean errors ($m = 12.5$) than perceiving types ($m = 10.3$), $t(88) = 1.46$, $p = .07$. Apparently the tendency for the perceiving types to be flexible and seek efficiency in processes applied to these problems.

Hypotheses group D: When performances of individuals troubleshooting a faulty component are grouped according to psychological type preferences, the following

results are anticipated for the mean number of redundant tests used to identify the faulty component:

1. When individuals are grouped according to the extraversion-introversion preference, introverted types will use fewer mean redundant tests to identify the faulty component than extraverted types ($p < .05$).

This hypothesis was supported to the required level of statistical significance. Extraverted types committed more redundant tests ($m = 1.1$) than introverted types ($m = 0.4$), $t(88) = 2.19$, $p < .05$. The extraverted types were expected to commit a greater number of redundant tests than introverted types due to extraverts' tendencies to act more impulsively than introverted types. Introverts are generally more reflective before acting than extraverted types. This exercise probably tapped the introverts' tendency to internalize a problem, as not a great deal of external manipulation was allowed; most of the the work necessary to solve the problem was mental.

2. When individuals are grouped according to the sensing-intuition preference, intuitive types will use fewer mean redundant tests to identify the faulty component than sensing types ($p < .05$).

Intuitive types used fewer redundant tests ($m = 0.4$) than sensing types ($m = 0.9$) as expected, but the hypothesis was not supported to a level of statistical significance ($t(88) = 1.43$, $p = .08$).

3. When individuals are grouped according to the thinking-feeling preference, thinking types will use fewer mean redundant tests to identify the faulty component than feeling types ($p < .05$).

There was no difference in the use of redundant tests between thinking types and feeling types ($m = 0.7$). This hypothesis was not supported.

4. When individuals are grouped according to the judging-perceiving preference, judging types will use fewer mean redundant tests to identify the faulty component than perceiving types ($p < .05$).

This hypothesis was not supported; judging types used more redundant tests ($m = 0.9$) than perceiving types ($m = 0.4$), $t(88) = 1.94$, $p < .05$. Judging types, despite their tendency to want to be right, are more likely to try to make things come out "the way they ought to be." This apparently was revealed in their use of retests. The judging types did not trust or did not believe an earlier test, so they tested a component again.

Hypothesis E: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by age, there will be no significant correlations ($p > .05$) between measures of performance and age.

This hypothesis was tested with Pearson product-moment correlation analysis using age as the independent variable and performance measures as the dependent variables. Age was not a significant factor in influencing performance on total mean time ($r = -.05$, $p = .33$), total mean number of tests ($r = .15$, $p = .08$), or total mean number of errors ($r = .02$, $p = .43$). However, age was revealed as a significant factor ($r = .20$, $p = .03$) in influencing total mean number of redundant tests; older subjects used fewer redundant tests, probably due to experience.

Hypothesis F: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by years of experience in electronic troubleshooting, there will be no significant correlation ($p > .05$) between measures of performance and years of experience.

When tested with Pearson product-moment correlation analysis, years of experience were correlated to a significant level for the total mean time ($r = -.22$,

$p = .02$). Years of experience were not correlated to significant levels with total mean tests ($r = -.13$, $p = .10$), total mean number of errors ($r = -.13$, $p = .11$), or for mean number of redundant tests ($r = -.12$, $p = .12$). Although common sense suggests a relationship between years of experience in electronics and performance in troubleshooting a logic network, the problem solving instrument was selected to minimize influence between experience and performance. Hypothesis F was supported for performance measures of number of tests, number of errors, and number of redundant tests, but rejected for mean time to solution.

Hypothesis G: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by years of education, there will be no significant correlation ($p > .05$) between measures of performance and years of education.

Pearson product-moment correlation was used to determine a significant correlation between years of education and mean number of redundant tests ($r = -.20$, $p = .03$). No significant correlations were found between years of education and total mean time ($r = -.16$, $p = .07$), total mean number of tests ($r = -.08$, $p = .23$), and total mean number of errors ($r = -.16$, $p = .07$). Hypothesis G was supported for the measures of mean time, mean number of tests, and mean number of errors, but rejected for mean number of redundant tests.

Hypothesis H: When performances of individuals troubleshooting a faulty component in a simulated logic network are grouped by sex, there will be no significant difference ($p > .05$) between measures of performance.

The results of two-tailed t-tests revealed a very large and unanticipated difference between performances of men ($m = 699.94$ sec) and women ($m = 1231.47$ sec) for measures of total time ($t(88) = 2.88$, $p < .01$). Similarly, there was a significant difference between performances of men ($m = 38.5$) and women ($m = 48.1$)

for the total number of tests ($t(88) = 2.11$, $p < .05$). While there were differences between men and women in the performance measures of total errors ($t(88) = 1.19$, $p = .25$) and total redundancies ($t(88) = 1.88$, $p = .06$), these differences were not statistically significant ($p > .05$). Results for men and women are summarized in Table 4-2.

Table 4-2
Differences in Problem Solving
Performance Measures for Men and Women

Sex	Mean Total Time to Solution (sec)	Mean Total Number of Tests	Mean Total Number of Errors	Mean Total Number of Redundant Tests	
Men	699.94**	38.5*	10.9	0.5	(n=71)
Women	1231.47**	48.1*	14.3	1.2	(n=19)

* denotes a significant difference between means ($p < .05$)
** denotes a significant difference between means ($p <. 01$) N=90

Post-Hoc Analyses

It was not anticipated that age, years of experience, years of education, and sex would affect performance to significant levels. The discovery of significant differences between performances of men and women for time to solution and number of tests, the significant correlation between age and mean number of redundant tests, and significant correlations between years of experience and number of redundant tests led to post-hoc analyses to answer the following question: Are performance measures affected to a significant degree by the Myers-Briggs preferences, by variables of age, sex, experience, and education, or by a combination of independent variables?

To test for interactions and influences between variables, correlation analysis was performed on all independent variables. While some of the findings were expected

(for example, age being correlated with experience), other relationships were more subtle. Results are summarized in Table 4-3.

Table 4-3
Product-Moment Correlations
Between Independent Variables

	Sex	Age	Grd	Exp	EI	SN	TF	JP
Sex	-	.20*	.12	.50**	-.06	.06	-.40**	.06
Age		-	-.16	.55**	.06	-.06	-.04	.07
Grade			-	-.22*	.08	.16	-.03	-.18*
Exp				-	.14	-.03	-.30*	.10
EI					-	-.06	-.04	.07
SN						-	-.02	.17
TF							-	.04
JP								-

**denotes a significant correlation between variables ($p < .01$)
*denotes a significant correlation between variables ($p < .05$)

Many of the intercorrelations between type preferences were consistent with findings from other MBTI studies. First, there were no significant relationships between each of the type preferences for this sample, consistent with the observed independence of the MBTI preference scales (Myers & McCaulley, 1985, p. 150). Second, there was a significant correlation between the TF preference and sex ($r = -.40$, $p < .01$), a trend noted in other MBTI studies (Myers & McCaulley, 1985, p. 45). Also consistent with other MBTI data (Macdaid, Kainz, & McCaulley, 1984) was the correlation between the JP preference and grade completed in school ($r = -.18$, $p < .05$). This indicated that judging types in this sample generally completed more years of school.

Several variables correlated strongly with sex. These indicated that the men of the sample generally were older, had more years of electronic troubleshooting experience, and more years of education than the women. These correlations were not surprising, as they fit the characteristics of the sample.

As seen in Hypothesis H, total time to solution was correlated with sex of individuals. Not surprisingly, a significant correlation (r = -.40, p < .001) was found between sex and TF type preference. This was consistent with Myers-Briggs Type Indicator data that "females have relatively more F types and males have relatively more T types" (Myers & McCaulley, 1985, p. 45). But a question was raised: Was total time performance influenced by sex, by TF preference, or by the combination of factors?

Although this study was correlational in nature, it seemed appropriate to use partial correlation analysis and regression analysis to ascertain the relative influence of the demographic and type variables on the performance variables, treating the latter as dependent variables. However, correlations do not denote causality and should not be interpreted as such.

Partial correlation analysis to remove the effect of the TF type preference revealed a significant correlation between total mean time and sex (r = -.36, p < .001). However, a similar analysis suggested that the TF type preference, with the influence of sex statistically removed, was not influencing total mean time to a significant level (r = .07, p = .27).

Similarly, performance for mean number of tests was affected to a significant extent by sex of the subjects; men used fewer tests (m = 38.5) than women (m = 42.1), $t(88)$ = 2.21, p < .05. As noted in Hypothesis B-2, total test performance is also related to the SN type preference. However, no statistically significant correlation was found between sex and SN type preference (r = .06, p = .30), indicating that each factor was acting independently.

Variables of years of education, age, the EI type preference, and the JP type preference correlating with the use of redundant tests suggested a multiple regression analysis to indicate whether any single variable was influencing performance more than others. Multiple regression indicated that factors of sex ($F(4,85) = -2.63$, $p < .05$), the EI preference ($F(4,85) = -3.02$, $p < .01$), and the JP preference ($F(4,85) = -2.01$, $p < .05$), and age ($F(4,85) = 2.84$, $p < .01$) affected the number of redundant tests at statistically significant levels. Partial correlation was then used to test the independent influence from each variable and revealed that each factor was independently correlated with mean number of redundant tests. Men used fewer redundant tests than women ($r = -.27$, $p < .01$), older subjects used fewer redundant tests than younger subjects ($r = .29$, $p < .01$), introverted types used fewer redundant tests than extraverted types ($r = -.31$, $p < .01$), and perceiving types used fewer redundant tests than judging types ($r = -.21$, $p < .05$).

An interesting outcome was that years of education significantly correlated with the number of redundant tests, using the Pearson product-moment correlation, as noted in Hypothesis G. Also, the two-tailed t-test analysis for Hypothesis H indicated no significant difference for the use of redundant tests between men and women. However, the partial correlation analysis revealed a significant correlation between sex and the number of redundant tests, without a significant correlation between years of education and the number of redundant tests. Apparently, intercorrelations between sex, years of education, and other independent variables affected these outcomes for performance measures.

From the post-hoc analysis, significant differences between type preferences and performance measures were supported despite some correlations with other independent variables. Extraverted types used significantly more redundant tests than introverted types, intuitive types used significantly fewer tests and committed significantly fewer

errors than sensing types, and perceiving types used significantly fewer tests and fewer redundant tests than judging types.

Analyses of Subsidiary Questions

Subsidiary questions from Chapter 1 include the following: Do the different psychological types exhibit patterns of troubleshooting behavior that are consistent with other behavior patterns associated with their respective types; do some psychological types take cognitive shortcuts and mentally "leap" to identification of a fault; do people of different psychological types differ in their abilities to distinguish between the feasible and nonfeasible set of components; do some psychological types demonstrate greater anxiety or frustration than other types as problem complexity increases; do people of the different psychological types differ in their perceptions of problem difficulty; and as problem complexity increases, does the degree of flexibility in changing problem strategies differ among people of different type preferences. In the following sections each of the subsidiary questions is addressed.

Troubleshooting Styles and Cognitive Shortcuts

From anecdotal records and observations, it was interesting to see the emergence of four distinct patterns of problem solving strategies among subjects. Based on the subjects' methods, terms were invented to describe the four strategies: systematic, shotgun, serial, and sniff. Equally interesting was the tendency of each subject to maintain consistency with a particular strategy; no subject changed his or her particular strategy while completing the five exercises.

Systematic troubleshooters searched for the fault by examining the given outputs and methodically working backward through the network, testing components which fed known failing components. The fault was identified by checking all possible inputs for a

known bad component. The subject would reduce the section of the network being tested to a set of two or three possible components and systematically test the outputs of components in the section. The method involved a moderate cognitive effort and resulted in a high success rate with a fairly large number of tests. This was the favored approach and nearly 80% of the subjects used this technique.

Individuals who employed the shotgun strategy randomly tested and replaced components. The subjects did not use the given clues or knowledge gained while testing components, instead relying on a scattered pattern of tests and replacements to "target" the fault. Little cognitive effort was involved because the subjects merely guessed. Five subjects used this strategy, with wide variations in their performance measures, depending on each subject's ability to guess.

The serial strategy involved testing components in a serial manner (test component 1, test component 2, test component 3, etc.) until a component with a faulty output was discovered. Five subjects used this low-effort approach which generally resulted in low solution times with a moderate number of tests.

Finally, seven subjects were identified as "sniffers," individuals who demonstrated a remarkable ability to identify the fault with a very few number of tests and replacements. The sniffers would study the displayed network for a short time then test or replace a component that would either be the fault or a component directly linked to the fault. It seemed as though the sniffers could sort the relationships between known outputs and component links entirely in their minds and identify the fault without much physical testing. This was a successful approach that involved high cognitive effort.

There was no apparent relation between the four troubleshooting strategies and Myers-Briggs type preferences. No single type preference dominated any category of troubleshooting style. Nor were there any indications of other independent variables

relating to selection of a particular strategy, leading to the speculation that a combination of factors was influencing troubleshooting styles.

Distinguishing Between Feasible and Nonfeasible Sets

Using low numbers of tests and low numbers of errors as indicators, intuitive types may be more adept than sensing types in the ability to distinguish between the feasible and nonfeasible set of components. A significant difference in performance was noted between intuitive types and sensing types with regard to the number of tests ($t(88) = 2.31$, $p < .05$) and number of errors ($t(88) = 2.28$, $p = .01$), pointing to a tendency by intuitive types to avoid testing nonfeasible components.

Anxiety Levels and Perceptions of Difficulty

There were no observed differences in anxiety or frustration levels related to type preferences. Only a small number of subjects exhibited any test anxiety. Most of the subjects seemed to enjoy the challenge of the exercise.

Using responses from question 5 of the post-exercise questionnaire (How difficult were the exercises?) as a measure of perceived difficulty no relationship was observed between perceived difficulty and type preferences. Across all type preferences, 62% of respondents judged the exercise as moderately easy, 32% judged it moderately difficult, 3% determined it very easy, and the remaining 3% assessed it as very difficult.

Flexibility of Solution Strategies

Degree of flexibility in changing problem solving strategies was not directly measured in this study. But, if the measures of performance in this study (time, tests, errors, and redundancies) were indicators of flexibility, then it can be argued that the

perceiving types were more flexible than the judging types for troubleshooting these types of logic problems. Perceiving types consistently outperformed judging types on these exercises, providing support to MBTI theory that mental flexibility allows perceiving types to make changes to deal with problems easier than judging types. This contrasts with the tendency of judging types to make things come out the way "they ought to be" and to decide things often before all the facts are known. This may explain why the expectations in Chapter 1 for JP type preferences were wrong; these problems may rely more on mental flexibility and shifting strategies than originally considered, and the perceiving preference may be a strong influence in this regard.

Results from Post-Exercise Questionnaire

The purpose of the post-exercise questionnnaire was to check for interference in problem solving performance from the computer-driven methodology and to gather data on years of experience in electronics. The results are summarized below.

Question 1--How Many Years Have You Been in the Electronics Field

The results to question 1 are summarized in Table 3-4. Fifty percent of the subjects had more than 10 years of experience in electronics with a fairly even distribution of one to 10 years experience for the remaining half of the sample.

Question 2--Did You Find the Exercise Useful for Practicing General Troubleshooting Skills

Twenty-eight percent of the subjects evaluated the exercise as "very useful," 48% stated it was "somewhat useful," and 24% evaluated it "not very useful." Overall, it appeared that the exercise was perceived by experienced, professional troubleshooters as a useful tool for practicing troubleshooting.

Question 3--Do You Like Learning With a Computer as an Instructional Tool

Seventy-one percent of the subjects indicated they liked learning with a computer "a lot." Eighteen percent responded "not very much," 8% responded "not at all," and 3% responded "this is the first time I have ever used the computer for instruction." These results indicated that the computer was generally perceived by these subjects as a viable tool for instruction.

Question 4--How Well Did You Like These Exercises

Thirty-one percent of the subjects stated they like the exercises "a lot." Thirty-nine percent responded with "somewhat," 20% responded "not very much," and 10% stated "not at all." The responses indicated that the exercises were viewed somewhat favorably by the subjects.

Question 5--How Difficult Were the Exercises

Only eight percent of the subjects evaluted the exercises as "very difficult", 29% evaluated them as "moderately difficult," 47% deemed them "moderately easy," and 16% classified them "very easy." The results indicate that the problems selected for the exercise were perceived as relatively easy overall. This could have imposed an undetermined ceiling effect on the results.

Question 6--How Would You Generally Rate Yourself as an On-The-Job Troubleshooter

Sixteen percent of the subjects classified themselves as "very proficient," with 42% claiming they were "proficient." Thirty-one percent of the subjects stated "it depends on the equipment and problem," 8% said they "sometimes have trouble," and only 3% admitted they "usually have trouble." However, no relationship was evidenced between performance on the exercises and subjects' self-classification.

Question 7--Would You Recommend Exercises Like These to Individuals Wishing to Improve Their Troubleshooting Skills

Forty-three percent of the subjects responded "yes," 41% said "depends on the individual," and 16% said "no." The results indicated that the exercise was regarded somewhat positively by the subjects.

Summary

Some of the expectations based on Myers-Briggs theory were supported by the findings to the required level of statistical significance ($p < .05$). Individuals with the preference for intuition used fewer tests and committed fewer errors than individuals with sensing preference. Extraverts committed more redundant tests than introverts.

Contrary to expectations, perceiving types used less time, fewer tests, and fewer redundant tests, and they made fewer errors than judging types. Statistically significant differences ($p < .05$) were observed for mean number of tests and mean number of redundant tests for the JP type preference.

Other factors influenced results, often to significant levels. Sex was a significant factor in time to solution and number of tests. Age was a significant factor in the number of redundant tests; older subjects used fewer tests.

Some of the demographic and type preference variables were correlated to significant levels ($p < .05$) with each other. A statistically significant correlation was found between sex and the TF type preference, making it appear that the TF type preference was a strong influence in total time to solution. Sex and experience were correlated (for this sample group, men had more years experience in electronic troubleshooting than women), age and experience were correlated (men were older than women in this sample), and the TF type preference was correlated with years of experience (the thinking types in this sample had more years experience).

Anecdotal records revealed four distinct strategies of troubleshooting: systematic, serial, shotgun, and sniff. Subjects tended to use the same problem solving strategy throughout the exercise. Results from a post-exercise questionnaire indicated no affective interference in performance results and indicated a generally positive response to the use of the computer and this type of exercise for providing troubleshooting practice.

Some intercorrelations between independent variables raised questions concerning the degree of influence of type preference on troubleshooting performance. However, some post-hoc analyses suggested that Myers-Briggs type preferences affect performance on problem solving logic exercises. Statistically significant differences were observed for five of the relationships between type preferences and performance measures. And, 11 of 16 expected outcomes were supported in direction, though not to statistically significant levels. But, Myers-Briggs type preferences were not the sole source of influence on problem solving behavior.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

Davis (1966) was right when he wrote, "research in human problem solving has a well-earned reputation for being the most chaotic of all identifiable categories of human learning" (p. 36). This study was an attempt to measure performance using a simple troubleshooting problem but the complexity of measuring human problem solving was quickly discovered.

The fundamental question remains: Do Myers-Briggs type preferences correlate with performance in solving computer-simulated logic problems? The answer is a qualified yes.

Myers-Briggs type preferences are related to performance in troubleshooting logic networks, particularly the sensing and intuitive preferences. But the type preferences share the stage with variables of age, experience, sex, and years of education influencing problem solving performance to varying degrees. And there are undoubtedly other factors related to troubleshooting performance waiting to be discovered.

For these exercises, SN differences for two of the performance measures, total mean number of tests and total mean number of errors, were statistically significant ($p < .05$). The differences for the measures of total mean time to solution and total mean number of redundant tests, while not statistically significant, were large and in line with predicted results. The consistency between theory-based predictions and empirical results indicate that sensing and intuition are important aspects of troubleshooting.

The judging and perceiving type preferences were also shown to relate to total mean number of tests and total mean number of redundant tests at statistically significant levels ($p < .05$). And a large and statistically significant difference ($p < .05$) was observed for the use of redundant tests by extraverted and introverted types.

If differences between MBTI type preferences relate to differences in problem solving behavior as suggested by these findings, then instructional designers and trainers should look for advances in training by applying the research relating type preferences and learning styles. As discussed in Chapter 2, extraverts tend to prefer group learning, while introverts like lectures and individualized work. Sensing types prefer demonstrations, laboratories, and computer-aided instruction, while intuitive types find self-instruction helpful and like courses that require self-initiative and self-paced learning. Thinking types prefer instructor-led courses with a logical, systematic approach to information. Feeling types value personal relationships while learning and attempt to establish a personal rapport with the teacher. Judging types like traditional test-driven instruction, while perceiving types prefer problem solving and discovery approaches to instruction.

An individual's type preferences can and should be tied to the training process. It will, of course, make the process more unwieldy and complex. However, complexity in the training process is necessary if we are to allow each individual to utilize fully the unique gifts that go with each preference and to expand the individual's range of abilities in each preference dimension.

Each dimension of psychological type comes into use during problem solving. Isabel Myers described a systematic problem solving approach that applies principles of psychological type:

> When there is a problem to deal with: 1) use sensing to gather the relevant facts and face them realistically; 2) use intuition to discover new possibilities and all

> the actions that might be taken to improve the matter; 3) use thinking-judgment to analyze all the consequences, good or bad, of each action that might be taken; and, 4) use feeling-judgment to weigh the value, to self and to others, of what will be gained or lost by these solutions. (Myers & McCaulley, 1985, p. 55)

Trainers of troubleshooters need to recognize each individual's strengths and weaknesses in psychological type and be willing to explore ways to develop an individual's abilities throughout the dimensions. Applying principles from type theory to troubleshooting training is an area that invites further consideration for improving troubleshooting performance.

The study of human problem solving, while complex, is an area of intrigue and promise. This study can easily be extended to explore the mysteries of problem solving, provide more insight to MBTI theory, examine cognitive events that occur during problem solving, and develop procedures for streamlining the task of training individuals engaged in complex fault isolation.

There are several ways to expand this study. One is to broaden the range of subjects to include people from various backgrounds, occupations, and cultures. The sample of engineers and technicians used in this study did not represent the distribution of types across the general population. It would be interesting to see if the observed behaviors from this group would match other subgroups, such as aeronautical engineers, accountants, physicians, construction workers, and even groups from other cultures.

The range of problems used in this study was purposely held narrow. To explore fully the relationships between psychological type and problem solving, a wider range of problems must be applied to individuals of various type preferences. Games, simulations, anagrams, problems requiring physical manipulation of objects, problems requiring human interaction and communication skills, open-ended problems requiring creative and non-conventional thinking, and problems requiring group dynamics and teamwork are possibilities for exploration.

Additional research relating problem solving and other dimensions of personality is much needed. Technology is expanding at a much faster rate than the human ability to understand increasingly complex systems. Many psychological and educational instruments should be used to link other dimensions of personality with problem solving performance. Any links between psychological constructs and problem solving behavior may help psychologists, instructional designers, and trainers to understand, predict, and improve problem solving performance.

Research is also needed to examine the cognitive shifts that occur during phases of problem solving. Expanding this study to include a fine-grained examination of the mental processes during troubleshooting would be welcomed.

The exercises in this study could be applied as a training tool to explore the effects of extended practice with the computer-simulated exercises. Technical trainers are finding that traditional modes of instruction are inadequate for the increased complexity of equipment and are searching for new and better tools to quickly and efficiently improve performance.

A limitation of this study was the lack of sufficient numbers of subjects across all MBTI whole types to permit analyses of variations of performance across types. The number and type of subjects should be expanded to include sufficient numbers of subjects in each type to examine whole type differences in problem solving behavior.

Other possibilities include the development of curriculum models and instructional methods that apply principles of type theory to help people expand the range of functioning comfortably across the type preferences. For example, a person with a strong preference for sensing must be helped to recognize the strengths of observational power and to extend the less-developed powers of intuition in considering possibilities to fit the facts being gathered by the senses. Exercises to stimulate an

individual's requirement for intuition or other Myers-Briggs dimensions would be important tools for further study.

As other researchers approach the task of exploring and improving problem solving performance, the words of Norman (1983) may help to keep things in perspective:

> People's mental models are apt to be deficient in a number of ways, perhaps including contradictory, erroneous, and unnecessary concepts. As designers, it is our duty to develop systems and instructional materials that aid users to develop more coherent, useable mental models. As teachers, it is our duty to develop conceptual models that will aid the learner to develop adequate and appropriate mental models. And as scientists who are interested in studying people's mental models, we must develop appropriate experimental methods and discard our hopes of finding neat, elegant mental models, but instead learn to understand the messy, sloppy, and indistinct structures that people actually have. (p. 7)

APPENDIX A
INSTRUCTIONS FOR THE SUBJECTS

Instructions Read Orally by the Administrator

"Today you will be participating in an exercise to measure performance in solving a logic problem. The problem involves identifying a single faulty component in a simple logic network.

"The exercises will be completed on an IBM personal computer, which, in a moment, will provide you with additional instructions and a sample exercise. There is no risk involved in completing the exercises.

"The results of the exercise will be used in a study to evaluate instructional exercises for people involved in troubleshooting electronic equipment. This study is being conducted through the College of Education at the University of Florida. Your results are confidential and will not be tied in any way to your job performance. Your supervisor will not be informed of these results unless you tell him or her.

"Your cooperation is greatly appreciated in helping to add to the limited knowledge on how to train electronic maintenance personnel. You will not be paid to perform the exercises and you may choose not to perform the exercise or to quit at any time.

"Do you have any questions?"

Instructions Displayed on the Computer Screen

You will be given five exercises to troubleshoot a logic network. The object is to identify the single faulty component in the network.

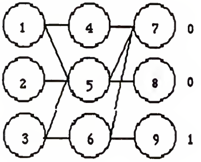
Components in the network are like logical "and" gates. They output a 1 if all inputs are good (equal to 1) and output a 0 if any input is bad (a zero). The faulty component, though, outputs a zero even though all inputs are 1. The result of the fault is carried through the remainder of the network. Outputs for the entire network are shown on the right side.

To identify the bad component, you may test and replace components. To test a component, use the mouse device to move the cursor over the desired component and press the left button on the mouse. The results of the test will be displayed next to the component (1 for good, 0 for fault). When you feel you have identified the fault, replace the component by moving the cursor over the suspected component and press the center button on the mouse. You will be informed whether you have succeeded in identifying the fault.

Try to identify the fault in a minimum number of steps, using as few tests and replacements as possible. Try to perform as quickly and as efficiently as possible.

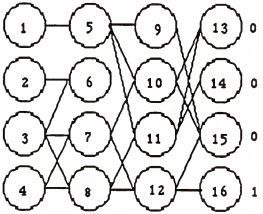
A sample will appear when you depress RETURN. Complete the sample exercise and continue with the five exercises.

APPENDIX B
EXERCISES USED IN THE STUDY



Fault = 2

Figure C-1
Sample Exercise



Fault = 5

Figure C-2
Exercise Number 1

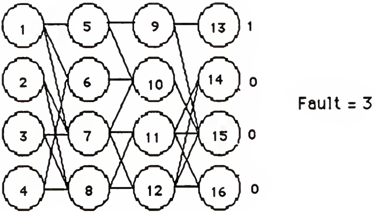


Figure C-3
Exercise Number 2

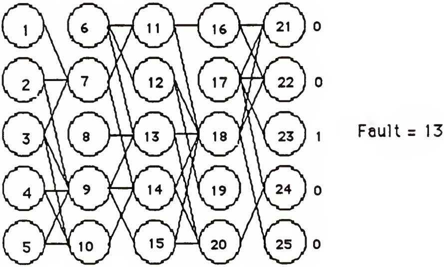


Figure C-4
Exercise Number 3

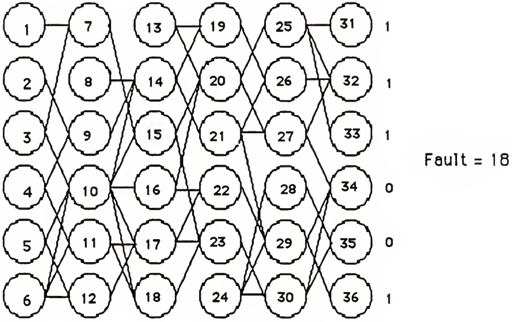


Figure C-5
Exercise Number 4

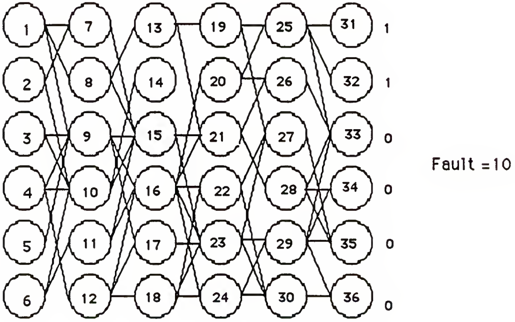


Figure C-6
Exercise Number 5

APPENDIX C
POST-EXERCISE QUESTIONNAIRE

NAME ______________________________

Please respond to each question concerning your feelings for the problems just completed. Place the letter for each answer in the space provided.

____1. How many years have you been in the electronics field?
A. 0-1 years
B. 2-4 years
C. 5-7 years
D. 8-10 years
E. More than 10 years

____2. Did you find the exercise useful for practicing general troubleshooting skills?
A. Very useful - proficient troubleshooters could use it
B. Somewhat useful - it is limited in its application to problems
C. Not very useful - it is too far removed from real problems

____3. Generally, do you like learning with a computer as an instructional tool?
A. A lot
B. Somewhat
C. Not very much
D. Not at all
E. This is the first time I have ever used the computer for instruction.

____4. How well did you like these exercises?
A. A lot
B. Somewhat
C. Not very much
D. Not at all

____5. How difficult were the exercises?
A. Very difficult
B. Moderately difficult
C. Moderately easy
D. Very easy

____6. How would you generally rate yourself as an on-the-job troubleshooter?

A. Very proficient
B. Proficient
C. Depends on the equipment and problem
D. Sometimes have trouble
E. Usually have trouble

____7. Would you recommend exercises like these to individuals wishing to improve their troubleshooting skills?

A. Yes
B. Depends on the individual
C. No

COMMENTS:

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BIOGRAPHICAL SKETCH

Mark Wayne Morgan began his professional career in 1976 as a high school science teacher following graduation with a bachelor's degree in science education from Florida Technological University in Orlando, Florida (now the University of Central Florida). While teaching, he observed vast differences among students' interests and abilities, sparking a desire to return to graduate school part-time to expand his repertoire of instructional methods to accommodate these differences.

Following graduation with a master's degree in science education from the University of Central Florida in 1980, Mr. Morgan worked for a year with a private engineering firm. He returned to education as a faculty member of a private business college in 1981. Soon after he was promoted to dean of instruction and was made responsible for the college's instructional staff and academic programs.

A need for greater understanding of processes for instruction and evaluation prompted his enrollment in the University of Florida doctoral program in education in 1982. In the fall of 1983, Mr. Morgan was introduced to Myers-Briggs type theory by Gordon Lawrence during Dr. Lawrence's course on instructional models. The theory helped Mr. Morgan understand consistencies in his own behavior and the attitudes and behaviors of other people. The research applying principles of psychological type theory to education appeared full of promise for helping people extend their personal gifts and abilities.

Mr. Morgan moved professionally to the Kennedy Space Center in late 1984 and began building a training program for electronic technicians and engineers.

Again, differences in individuals emerged, this time in training preferences and styles in electronic troubleshooting. These observed differences prompted this investigation, in hope of linking consistencies in observed troubleshooting behavior with psychological type preferences.

Mr. Morgan is active in the American Society for Training and Development (ASTD) and Toastmasters. An ISTJ, he lives in Orlando, Florida, with his wife and three children.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

Gordon D. Lawrence

Gordon D. Lawrence, Chairman
Professor of Educational Leadership

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

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This dissertation was submitted to the Graduate Faculty of the College of Education and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Education.

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